Volume 31 SEPTEMBER, 1947 Number 9

BULLETIN
of the
American Association *of* Petroleum Geologists

CONTENTS

PALEOZOIC AND MESOZOIC STRATIGRAPHY OF NORTHERN GROS VENTRE MOUNTAINS AND MOUNT LEIDY HIGHLANDS, TETON COUNTY, WYOMING *BY HELEN L. FOSTER* 1537

UPPER ORDOVICIAN SHALES IN CENTRAL KANSAS *BY HALL TAYLOR* 1594

MISSISSIPPIAN ROCKS OF MERAMEC AGE ALONG ALCAN HIGHWAY, NORTHERN BRITISH COLUMBIA *BY LOWELL R. LAUDON AND B. J. CHRONIC, JR.* 1608

EQUILIBRIUM OF FORM AND FORCES IN TIDAL BASINS OF COAST OF TEXAS AND LOUISIANA *BY W. ARMSTRONG PRICE* 1619

GEOLOGICAL NOTES

Revised Correlation of Jurassic Formations of Parts of Utah, Arizona, New Mexico, and Colorado *By A. A. Baker, C. H. Dane, and J. B. Reeside, Jr.* 1664

Classification of Faults *By Mason L. Hill* 1669

Triassic Deposits of Pecos Valley, Southeastern New Mexico *By Walter B. Lang* 1673

Preliminary Report on Salt Creek Field, Kern County, California *J. C. Beach* 1674

Paleogeography of South America (Correction) 1677

REVIEWS AND NEW PUBLICATIONS

1945 Reference Report on Certain Oil and Gas Fields of North Louisiana, South Arkansas, Mississippi, and Alabama, Vol. II *By B. Coleman Renick* 1678

Rockhounds of Houston, by Alva C. Ellisor *By A. R. Denison* 1681

Einführung in den Bau Amerikas, by Hans Stille *By W. A. Ver Wiebe* 1682

Late Mesozoic and Early Cenozoic History of Central Utah, by Edmund M. Spieker *By C. E. Dobbin* 1684

Leven en Materie, by J. H. F. Umbgrove *By Parker D. Trask* 1685

ASSOCIATION ROUND TABLE

Association Committees 1688

Membership Applications Approved for Publication 1691

Supplementary Membership List, September 1, 1947 1693

Report of Nominating Committee *By Frederic H. Lahee, chairman* 1697

MEMORIAL

Frederick Byron Plummer *By E. DeGolyer* 1698

Michael Marcus Valerius *By V. H. Hughes* 1700

AT HOME AND ABROAD

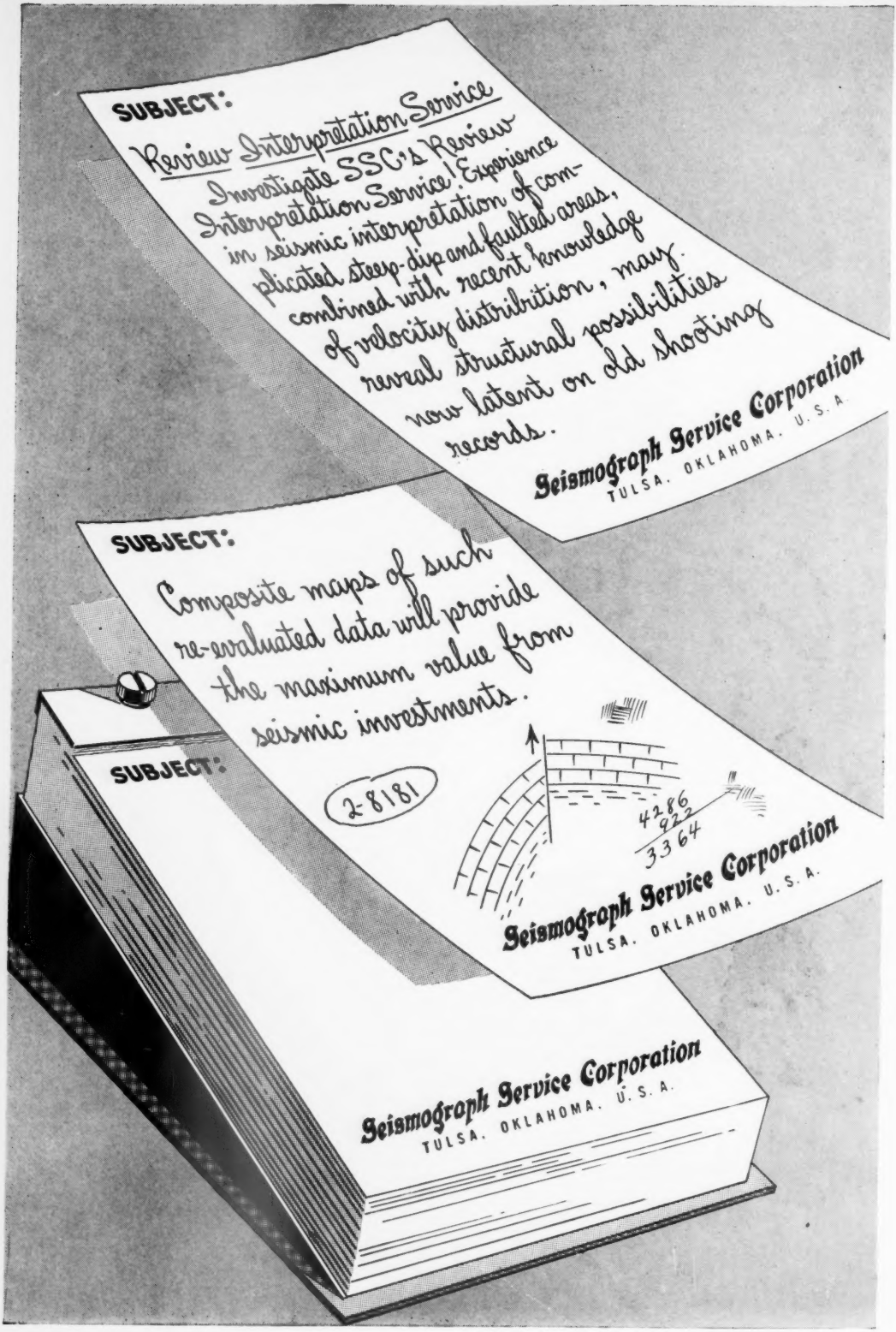
Current News and Personal Items of the Profession 1703

South Texas Regional Meeting, San Antonio, November 5-6, 1947 1704

Pacific Section Annual Meeting, Pasadena, November 6-7, 1947 1704

Eastern Interior Regional Meeting, St. Louis, January 14-15, 1948 1704

COPYRIGHT 1947, BY THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.


SUBJECT:
Review Interpretation Service
Investigate SSC's Review Interpretation Service! Experience in seismic interpretation of complicated, steep-dip and faulted areas, combined with recent knowledge of velocity distribution, may reveal structural possibilities now latent on old shooting records.
Seismograph Service Corporation
TULSA, OKLAHOMA, U.S.A.
SUBJECT:
Composite maps of such re-evaluated data will provide the maximum value from seismic investments.
2-8181
4286
922
3364
Seismograph Service Corporation
TULSA, OKLAHOMA, U.S.A.
SUBJECT:
Seismograph Service Corporation
TULSA, OKLAHOMA, U.S.A.

BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

OFFICE OF PUBLICATION, 708 WRIGHT BUILDING, TULSA, OKLAHOMA

C. L. MOODY, *Editor*
THE OHIO OIL COMPANY, SHREVEPORT 91, LOUISIANA

ASSOCIATE EDITORS

GENERAL	K. C. HEALD, Gulf Oil Corporation, Box 1166, Pittsburgh 30, Pa.
	HUGH D. MISER, U. S. Geological Survey, Washington 25, D. C.
	THERON WASSON, Pure Oil Company, 35 E. Wacker Drive, Chicago 1, Ill
APPALACHIANS	RICHARD E. SHERRILL, University of Pittsburgh, Pittsburgh 13, Pa.
NORTH-CENTRAL STATES	R. B. NEWCOMBE, Superior Oil Company, Grand Rapids, Mich.
KANSAS	EDWARD A. KOESTER, 302 Orpheum Building, Wichita 2, Kan.
OKLAHOMA	
Western	ROBERT H. DOTT, Oklahoma Geological Survey, Norman, Okla.
Eastern	JOHN L. FERGUSON, Amerada Petroleum Corp., Box 2040, Tulsa 1, Okla.
TEXAS	
North and Central	J. B. LOVEJOY, Gulf Oil Corporation, Fort Worth 1, Tex.
Northeastern	C. I. ALEXANDER, Magnolia Petroleum Company, Tyler, Tex.
San Antonio	JOHN R. SANDIDGE, Magnolia Petroleum Company, San Antonio 5, Tex.
Permian Basin	E. RUSSELL LLOYD, Box 1026, Midland, Tex.
GULF COAST	SIDNEY A. JUDSON, Texas Gulf Producing Company, Houston 1, Tex.
	MARCUS A. HANNA, Gulf Oil Corporation, Houston 1, Tex.
EASTERN GULF	HENRY N. TOLER, Southern Natural Gas Company, Jackson, Miss.
ARKANSAS AND NORTH LOUISIANA	ROY T. HAZZARD, Gulf Refining Company of Louisiana, Shreveport 93, La.
ROCKY MOUNTAINS	A. E. BRAINERD, Continental Oil Company, Denver 2, Colo.
CALIFORNIA	W. D. KLEINPELL, Box 1131, Bakersfield, Calif.
	E. R. ATWILL, Union Oil Company of California, 617 W. 7th, Los Angeles 14
CANADA	THEODORE A. LINK, Imperial Oil Limited, Toronto, Ontario
SOUTH AMERICA	HOLLIS D. HEDBERG, Gulf Oil Corporation, 17 Battery Pl., New York 4, N.Y.

THE BULLETIN is published by the Association on the 15th of each month.

EDITORIAL AND PUBLICATION OFFICE AND ASSOCIATION HEADQUARTERS, 708 Wright Building, 115 and 117 West Third Street, Tulsa, Oklahoma. Post Office, Box 979, Tulsa 1.

BRITISH AGENT: Thomas Murby & Co, 40 Museum Street, London, W. C. 1.

SUBSCRIPTION PRICE to non-members is $15 per year (separate numbers, $1.50), prepaid to addresses in the United States; outside the United States, $15.40.

CLAIMS FOR NON-RECEIPT must be sent within 3 months of date of publication, to be filled gratis.

BACK NUMBERS, if available, may be ordered from Headquarters. Price list on request.

	Mem.	*Non-Mem.*
Cloth-bound Bulletin, Vols. 12 (1928)–15 (1931) incl., each	$5.00	$6.00

SPECIAL PUBLICATIONS	*Mem.*	*Non-Mem.*
1929. Structure of Typical American Oil Fields, I	3.00	3.00
II	4.00	4.00
1936. Geology of Tampico Region	3.50	4.50
1936. Map of Southern California	.50	.50
1938. Miocene Strat. California	4.50	5.00
1941. Future Oil Provinces	1.00	1.50
1944. Tectonic Map of U. S.	2.00	2.00
1946. Directory of Geological Material in North America	.75	.75
1947 Comprehensive Index '17-'45	3.00	4.00

Communications about the Bulletin, manuscripts, editorial matters, subscriptions, special rates to public and university libraries, publications, membership, change of address, advertising rates, and other Association business should be addressed to

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

J. P. D. HULL, BUSINESS MANAGER
ELMER W. ELLSWORTH, ASSISTANT BUSINESS MANAGER
BOX 979, TULSA, 1, OKLAHOMA

Entered as second-class matter at the Post Office at Tulsa, Oklahoma, and at the Post Office at Menasha, Wisconsin, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized March 9, 1923.

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

Organized at Tulsa, Oklahoma, February 10, 1917, as the Southwestern Association of Petroleum Geologists. Present name adopted, February 16, 1918. Incorporated in Colorado, April 23, 1924. Domesticated in Oklahoma, February 9, 1925.

OFFICERS FOR THE YEAR ENDING APRIL, 1948

C. E. DOBBIN, *President*, Denver, Colorado
J. V. HOWELL, *Secretary-Treasurer*, Tulsa, Oklahoma
GEORGE S. BUCHANAN, *Vice-President*, Houston, Texas
C. L. MOODY, *Editor*, Shreveport, Louisiana

The foregoing officers and the *Past-President*, EARL B. NOBLE, Los Angeles, California, constitute the Executive Committee

DISTRICT REPRESENTATIVES (Terms expire after annual meetings of years shown in parentheses)

Amarillo: Elisha A. Paschal (48), Amarillo, Tex.
Appalachian: Fenton H. Finn (49), Pittsburgh, Pa.
Canada: C. S. Corbett (49), Calgary, Alberta
Capital: Carle H. Dane (48), Washington, D. C.
Corpus Christi: O. G. McClain (49), Corpus Christi, Tex.
Dallas: W. Dow Hamm (48), Dallas, Tex.
East Oklahoma: Frank R. Clark (48), Tulsa; Robert L. Kidd (48), Bartlesville; E. Floyd Miller (49), Sam H. Woods (49), Tulsa
Fort Worth: Lynn K. Lee (49), Fort Worth, Tex.
Great Lakes: Stanley G. Elder (48), Evansville, Ind.
E. E. Rehn (49), Mt. Vernon, Ill.
Houston: Ira A. Brinkerhoff (48), Shirley L. Mason (48), Olin G. Bell (48), Charles L. Lake (49), Harry C. Spoor, Jr. (49), Houston, Tex.
Michigan: Charles K. Clark (49), Saginaw, Mich.
New Mexico: Reuel L. Boss (49), Hobbs, N. Mex.
New York: G. M. Knebel (48), Hollis D. Hedberg (49), New York City.
Pacific Coast: Frank W. Bell (48), Sacramento; Claude E. Leach (48), Ventura; D. E. Taylor (48), Long Beach; Gordon R. Bell (49), Los Angeles; W. S. W. Kew (49), San Francisco; Lowell W. Saunders (49), Bakersfield.
Rocky Mountains: H. E. Christensen (48), Denver, Colo.; A. F. Barrett (49), Casper, Wyo.
Shreveport: B. W. Blanpied (49), Shreveport, La.
South America: H. G. Kugler (48), Point-a-Pierre, Trinidad, B. W.I.; J. M. Patterson (49), Caracas, Venezuela
Southeast Gulf: Henry N. Toler (49), Jackson, Miss.
Southern Louisiana: J. W. Hoover (49), New Orleans, La.
So. Permian Basin: Warren D. Anderson (48), F. H. McGuigan (49), Midland, Tex.
South Texas: Robert N. Kolm (48), George H. Coates (49), San Antonio
Tyler: C. I. Alexander (49), Tyler, Tex.
West Oklahoma: C. W. Tomlinson (48), Ardmore; John T. Sanford (49), Oklahoma City
Wichita: Frederick G. Holl (49), Wichita, Kan.
Wichita Falls: J. J. Russell, Jr. (48), Wichita Falls, Tex.

DIVISION REPRESENTATIVES

Paleontology and Mineralogy: James A. Waters (1948), Dallas, Texas; Henryk B. Stenzel (48), Austin, Texas

PACIFIC SECTION (Chartered, March, 1925)

MARTIN VAN COUVERING, *President*, consultant, 1734 Hillside Drive, Glendale, California
W. P. WINHAM, *Vice-President*, Standard Oil Company of California, 605 W. Olympic, Los Angeles, California
CLIFTON W. JOHNSON, *Secretary-Treasurer*, Richfield Oil Corporation, 555 Flower Street, Los Angeles
Membership restricted to members of the Association in good standing, residing in Pacific Coast states. Dues: $2.00 per year

SOUTH TEXAS SECTION (Chartered, April, 1929)

GUY E. GREEN, *President*, Santa Clara Oil Company, 1016 South Texas Building, San Antonio, Texas
J. BOYD BEST, *Secretary-Treasurer*, The Ohio Oil Company, 1417 Milam Building, San Antonio, Texas
Membership limited to persons eligible to Association membership. Dues: $2.50. Annual meeting in October.

EASTERN SECTION (Chartered, April, 1946)

BEN F. HAKE, *President*, Gulf Oil Corporation, 17 Battery Place, New York, N. Y.
L. G. WEEKS, *Secretary*, Standard Oil Company (N. J.), Room 2150, 30 Rockefeller Plaza, New York, N. Y.
Membership restricted to members of the Association in good standing, residing in New York district.

DIVISION OF PALEONTOLOGY AND MINERALOGY
SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

(Organized, March, 1927; affiliated, March, 1928; chartered, technical division, April, 1930)

JAMES A. WATERS, *President*, Sun Oil Company, Dallas, Texas
HENRYK B. STENZEL, *Secretary-Treasurer*, Bureau of Economic Geology, Austin 12, Texas

SEND DUES, SUBSCRIPTIONS AND ORDERS FOR BACK NUMBERS TO BOX 979, TULSA 1, OKLAHOMA
The Society and the Paleontological Society jointly issue six times a year the *Journal of Paleontology*, J. Marvin Weller, University of Chicago, Chicago 37, Illinois, and A. S. Warthin, Vassar College, Poughkeepsie, New York, editors: subscription, $6.00. The *Journal of Sedimentary Petrology*, W. H. Twenhofel, editor, University of Wisconsin, Madison, Wisconsin, is issued three times a year: subscription, $3.00. Single copies, *Journal of Paleontology*, $2.00; *Journal of Sedimentary Petrology*, $1.50. Society dues: with *Jour. Pal.*, $5.00; with *Jour. Sed. Petrology*, $3.00; with both, $8.00 per year.

AFFILIATED SOCIETIES (Dates of affiliation in parentheses)

Abilene Geological Society, Abilene, Texas (47). J. C. Hunter, Jr., Secy., 524 Mims Building.
Alberta Society of Petroleum Geologists, Calgary, Alberta. (31). D. G. Penner, Secy., McColl-Frontenac Oil Company, Ltd.
Appalachian Geological Society, Charleston, W. Virginia (31). R. L. Alkire, Secy., 603 Union Building
Ardmore Geological Society, Ardmore, Oklahoma (36). W. R. Johnson, Secy., The Texas Company, Box 539
Associacao Brasileira de Petroleo, Salvador, Bahia, Brazil (47). Earle F. Taylor, Secy., Conselho Nacional do Petroleo.
Corpus Christi Geological Society, Corpus Christi, Texas (43). H. C. Cooke, Secy., c/o O. G. McClain, 224 Nixon Building
Dallas Geological Society, Dallas, Texas (35). W. W. Newton, Secy., The Geotechnical Corporation, Box 7166
East Texas Geological Society, Tyler, Texas (32). Walter E. Long, Secy., Magnolia Petroleum Company, Box 780
Fort Worth Geological Society, Fort Worth, Texas (31). R. W. Dudley, Secy., Pure Oil Company, Box 2107
Houston Geological Society, Houston, Texas (32). Hershal C. Ferguson, Secy., 1208 Esperson Building
Illinois Geological Society (39). Charles Doh, Secy., Schlumberger Well Surveying Corporation, Box 571, Mattoon
Indiana-Kentucky Geological Society (38). P. L. Keller, Secy., Great Lakes Carbon Co., American Bldg., Evansville, Ind.
Kansas Geological Society, Wichita, Kansas (31). Don W. Payne, Secy., Sinclair Prairie Oil Company
Michigan Geological Society (37). H. J. Hardenberg, Secy., Michigan Geological Survey, Lansing
Mississippi Geological Society, Jackson, Miss. (41). Carl F. Grubb, Secy., Superior Oil Company, Tower Building
New Orleans Geological Society, New Orleans, La. (43). D. N. Rockwood, Secy., Union Producing Company, Box 1628.
North Texas Geological Society, Wichita Falls, Texas (38). D. T. Richards, Secy., 1709 Buchanan Street
Oklahoma City Geological Society, Oklahoma City, Okla. (31). L. R. Wilson, Secy., Carter Oil Company, 1300 Apco Tower
Panhandle Geological Society, Amarillo, Texas (32). Robert J. Gutru, Secy., Cities Service Oil Company, Box 350
Shawnee Geological Society, Shawnee, Oklahoma (31). Marcelle Mousley, Secy., Atlantic Refining Company, Box 169
Shreveport Geological Society, Shreveport, Louisiana (32). Richard T. Chapman, Secy., Stanolind Oil and Gas Co., Box 1092
Society of Exploration Geophysicists (32). Thomas A. Manhart, Secy., Seismograph Service Corp., Box 1590, Tulsa, Okla.
South Louisiana, Geological Society, Lake Charles, La. (37). W. Farrin Hoover, Secy., Stanolind Oil and Gas Company, Box 54
Southeastern Geological Society, Tallahassee, Fla. (44). Lois J. Schulz, Secy., The California Company, Box 371
Tulsa Geological Society, Tulsa, Oklahoma (31). V. L. Frost, Secy., Ohio Oil Company, Thompson Building
West Texas Geological Society, Midland, Texas (38). Charles F. Henderson, Secy., Stanolind Oil and Gas Company, Box 1540
Wyoming Geological Association, Box 545, Casper (45). George Steele, Secy., Northern Utilities Company
Yellowstone-Bighorn Research Association, Inc. (44). W. T. Thom, Jr., Secy., Princeton, N. J.

For Superior Geophysical Recordings

HALOID RECORD

SEISMOGRAPH RECORDING PAPER

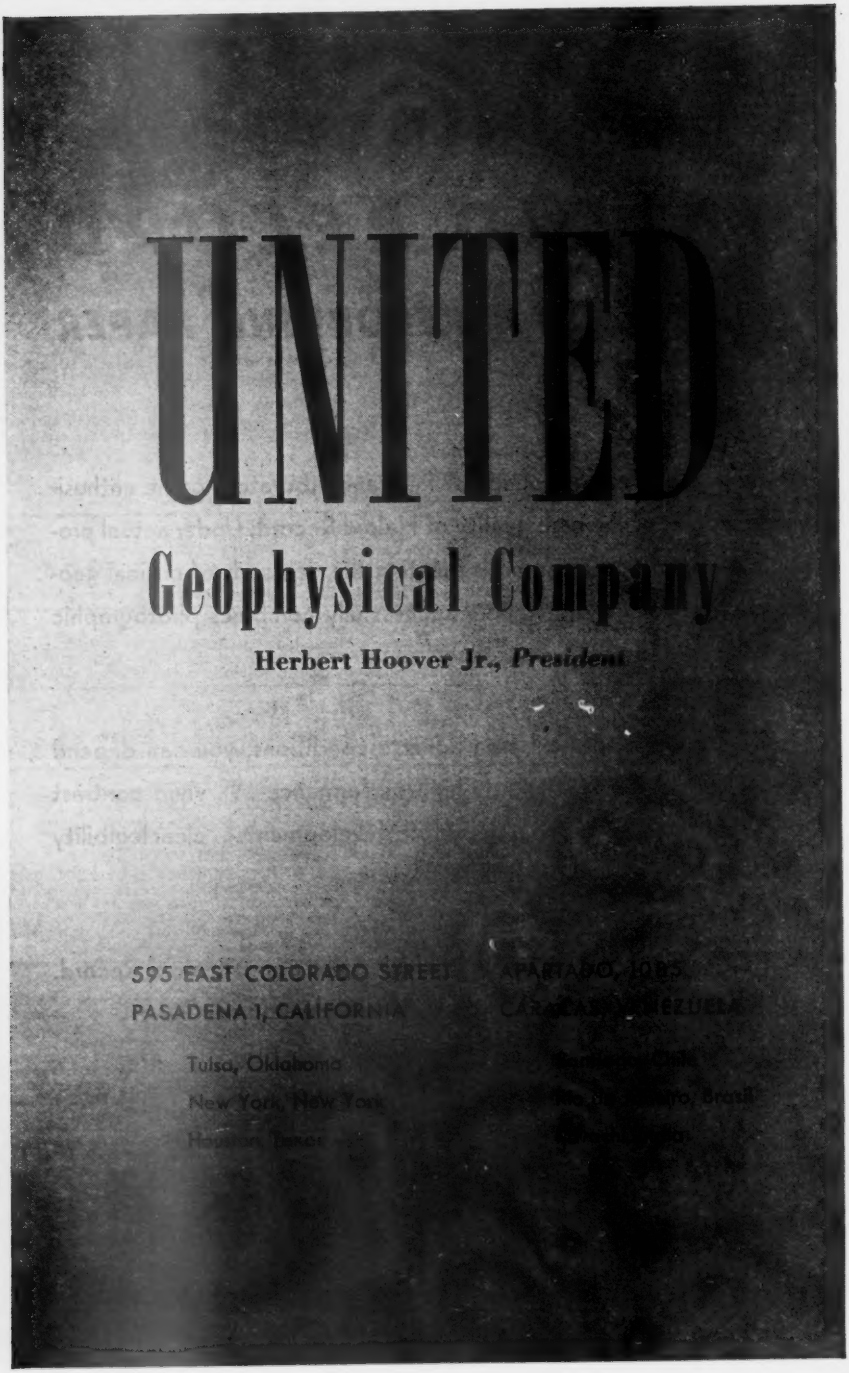
● From the proving grounds of field and laboratory come enthusiastic reports of the high quality of Haloid Record. Under actual production conditions, Record is meeting the demands of critical geophysicists. For Haloid Record successfully combines photographic excellence and abuse-resistance.

As a result, under extreme adverse conditions, you can depend upon Record for consistently high performance . . . vivid contrast . . . exceptional latitude . . . rapid free development . . . clear legibility . . . strength . . . and other ideal features.

That's why it will pay you to know more about Haloid Record. Write today for complete information and samples.

THE HALOID COMPANY

888 Haloid St. ***Rochester 3, N. Y.***


UNITED
Geophysical Company
Herbert Hoover Jr., President
595 EAST COLORADO STREET
PASADENA 1, CALIFORNIA
Tulsa, Oklahoma
New York, New York

A compass, bow and arrow
For me are quite enough,
For like an Indian Princess,
I really know my stuff.

I know the "quarry" that I seek
For I've made up my mind,
The guy I call "my oil man"
Is the smartest one I'll find.

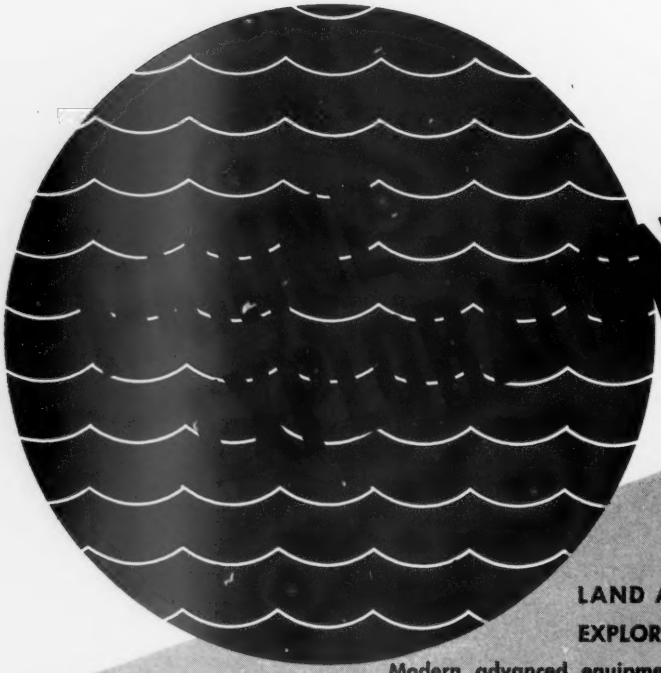
He always has Mayes-Bevan
Make a survey . . . says they're fine,
To localize an area
Before he spends a dime.

September 1947

SUN	MON	TUE	WED	THUR	FRI	SAT
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

MAYES-BEVAN
GRAVITY METER
M B
SURVEYS
COMPANY

KENNEDY BLDG. TULSA, OKLAHOMA



LAND AND MARINE
EXPLORATION WORK

Modern advanced equipment and trained crews for domestic and foreign exploration.

McCOLLUM EXPLORATION CO.

SINCE 1923

Pioneers in

REFRACTION SHOOTING
REFLECTION SHOOTING
WELL SHOOTING
MARINE SHOOTING

McCOLLUM SINCE 1923
Exploration Company

853 ESPERSON BUILDING • HOUSTON 2, TEXAS

Packing operations shortened... simplified... with these new...

Swivels

Check ✓ *THESE FEATURES...*

- Packing required only once every four months
- Only two parts subject to abrasive wear
- No slush can enter the bearing chamber
- New packing can be installed without disassembly of swivel
- Available in two sizes
- Early delivery

Geo. E. Failing Supply Co.

MANUFACTURERS • PORTABLE DRILLING EQUIPMENT

ENID, OKLAHOMA, U.S.A.

HOUSTON, TEXAS • MIDLAND, TEXAS • CASPER, WYOMING

Schlumberger
RADIO-ACTIVITY
(gamma ray)
WELL LOGGING
• Schlumberger, the originator of electrical well logging, now offers Radio-Activity (gamma ray) logging as a supplementary service for cased wells which have not been logged and for the occasional well in which an electrical log cannot be obtained.
The Schlumberger method of Radio-Activity logging is faster, more accurate, and more economical. It is performed by the same skilled field engineers who, through long experience in electrical well logging, have acquired a thorough knowledge of the subsurface.
This new Schlumberger service is now available in most fields.
SCHLUMBERGER WELL SURVEYING CORPORATION
Houston, Texas

Bulletin Advertisers

Advanced Exploration Company .....
American Optical Company .....
American Paulin System xlix
American Petroleum Institute xlv

Baker Oil Tools, Inc. viii
Baroid Sales Division .....
Barret, William M., Inc. .....
Bausch and Lomb Optical Company .....

Century Geophysical Corporation .....

Dowell Incorporated .....

Eastman Oil Well Survey Company .....
Economic Geology Publishing Company ..xxiv

Failing (Geo. E.) Supply Company v
Fairchild Aerial Surveys xlii
First Natl. Bank and Trust Co. of Tulsa .....
C. H. Frost Gravimetric Surveys xxxviii

General Geophysical Company xxiii
Geophysical Service, Inc. .....Cover iii
Geotechnical Corporation xxxviii
Gravity Meter Exploration Company xli

Halliburton Oil Well Cementing Company .xliv
Haloid Company iii
Heiland Research Corporation .....
Hercules Powder Company, Inc. .....
Hughes Tool Company .....Cover iv

Independent Exploration Company .....

Journal of Geology xxxix

Journal of Paleontology xlvi
Journal of Sedimentary Petrology xlvi

Keystone Exploration Company xxvii

Lane-Wells Company .....

Mayes-Bevan Company .....facing iv
McCollum Exploration Company .....facing v

National Geohysical Company l
North American Geophysical Company ..xxxvi

Oil Base, Inc. .....

Petty Geophysical Engineering Company .xxxiii

Reed Roller Bit Company lii
Republic Exploration Company xxxvii
Robert H. Ray Co. xxviii
Rogers-Ray, Inc. xxix

Schlumberger Well Surveying Corporation ..vi
Seismic Engineering .....
Seismic Explorations, Inc. xxv
Seismograph Service Corporation ....Cover ii
Society of Exploration Geophysicists xxiv
Southern Geophysical Company xl
Sperry-Sun Well Surveying Company .....
Sullivan Division, Joy Mfg. Co. .....xxx-xxxi

Thompson Tool Company, Inc. xxii
Triangle Blue Print and Supply Company ..xxiv

United Geophysical Company iv
Universal Exploration Company xxiv

Western Geophysical Company xxi

PROFESSIONAL CARDS

California ix
Colorado .....ix-x
Illinois x
Indiana x
Kansas x
Louisiana x
Maryland x
Mississippi xi
Montana xi
New Mexico xi
New York xi
North Carolina xi
Ohio xi
Oklahoma .....xi-xii
Pennsylvania xii
Texas ....xii, xiii, xiv, xv, xvi
West Virginia xvi
Wyoming xvi

GEOLOGICAL AND GEOPHYSICAL SOCIETIES

Appalachian xx
Ardmore xviii
Corpus Christi xix
Dallas xix
East Texas xix
Exploration Geophysicists xvii
Fort Worth xix
Houston xix
Illinois xvii
Indiana-Kentucky xvii
Kansas xvii
Michigan xviii
Mississippi xviii
New Orleans xvii
North Texas xix
Oklahoma City xviii
Pacific Section xvii
Panhandle xix
Pittsburgh xix
Rocky Mountain xvii
Shawnee xviii
Shreveport xviii
Southeastern xvii
South Texas Section xx
South Louisiana xviii
Tulsa xviii
West Texas xx
Wyoming xx

Articles for October *Bulletin*

Microbial Transformation of Molecular Hydrogen in Marine Sediments with Particular Reference to Petroleum — By Claude E. ZoBell
Geology and Water Resources of Southern Okinawa — By D. J. Cederstrom
Geomorphology of Depositional Surfaces — By W. Armstrong Price
Black Warrior Basin, Alabama and Mississippi — By Frederic F. Mellen
Stratigraphy of Outcropping Cretaceous Beds of Southeastern United States — By Watson H. Monroe
Cenozoic Deposits of Central Gulf Coastal Plain — By Grover E. Murray
Geology and Occurrence of Oil in Florida — By E. D. Pressler

BAKER

Cable Tool
CORE BARRELS

are still

YOUR BEST BET

to take cores

like these

Have you tried one lately?

BAKER OIL TOOLS, INC.

Houston • Tulsa • Los Angeles • New York

Volume 31 Number 9

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

SEPTEMBER, 1947

PALEOZOIC AND MESOZOIC STRATIGRAPHY OF NORTHERN GROS VENTRE MOUNTAINS AND MOUNT LEIDY HIGHLANDS, TETON COUNTY, WYOMING[1]

HELEN L. FOSTER[2]
Wellesley, Massachusetts

ABSTRACT

The northern Gros Ventre Mountains and Mount Leidy Highlands area is in western Wyoming south of Yellowstone National Park. This area was a shelf zone bordering a deeper part of the Rocky Mountain geosyncline during the Paleozoic and Mesozoic eras. Therefore, the sediments deposited were relatively thin as compared with those on the west and southwest. The rocks range from pre-Cambrian to Tertiary in age, with all of the systems present, excepting possibly the Silurian. The Paleozoic strata are about 3,500 feet thick, and the Mesozoic about 12,000 feet.

INTRODUCTION

Location.—The northern Gros Ventre Mountains and Mount Leidy Highlands are in western Wyoming south of Yellowstone National Park. Together they form the eastern margin of Jackson Hole, the intermontane valley which is

[1] Part of a dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the University of Michigan.

[2] Department of geology and geography, Wellesley College.

During the field work, which was carried on in the summers of 1944 and 1945, Camp Davis, the University of Michigan Rocky Mountain Field Station, was used as a base. The writer greatly appreciates the cooperation of the Camp Davis staff and particularly the assistance of Professor R. L. Belknap. In addition, assistance was given in the field by Camp Davis students: Ann Livesay, Lysbeth Fisher, Robert Christman, Margaret Pendleton, Jean Holforty, Ruth Bachrach, and others. Professor A. J. Eardley, director of geological field work at Camp Davis, deserves special thanks for aid in the field work and in the preparation of the manuscript. Professor L. B. Kellum, director of the Museum of Paleontology, University of Michigan, aided in identifying Cretaceous fossils and in writing the section on Cretaceous stratigraphy. Professor W. F. Hunt, chairman of the department of mineralogy, University of Michigan, checked some of the thin sections and offered suggestions on part of the manuscript. Professor K. K. Landes, chairman of the department of geology, University of Michigan, made many helpful suggestions. Professor J. E. Thornton, of the English department, College of Engineering, University of Michigan, assisted greatly in the preparation of the manuscript.

bordered on the west by the Teton Range. The Mount Leidy Highlands are generally considered to include the area between the Gros Ventre River and Buffalo Fork from the eastern border of Jackson Hole to the western margin of the Wind River Mountains. Mount Leidy, the highest peak (10,317 feet), is near the center of the area. The section of the Gros Ventre Range here discussed is south of the Gros Ventre River in the Mount Leidy and Grand Teton quadrangles.

In general, the strata crop out in the eastern third of the Grand Teton Quadrangle and the western half of the Mount Leidy Quadrangle, as shown on the United States Geological Survey topographic sheets.

The drainage of the region is into the Snake River, which flows southwestward through Jackson Hole. The principal streams from south to north are Flat Creek, the Gros Ventre River, Spread Creek, and Buffalo Fork (Fig. 5).

Purpose.—The data here presented are part of a more inclusive study of the northern Gros Ventre Mountains and Mount Leidy Highlands made during the summers of 1944 and 1945. Since this area has recently become of much interest in the exploration for oil, the information may be useful to petroleum geologists and others in correlating formations and in determining the Paleozoic and Mesozoic history of western Wyoming.

STRATIGRAPHIC COLUMN

(Tertiary formations not included)

Age	*Formation*	*Thickness (Feet)*	*Lithology*
Upper Cretaceous	Mesaverde	4,075±	Characterized by massive tan sandstone cliffs capped by ledges of more resistant red-brown sandstone; interbedded shales and a few lithographic limestones
Upper Cretaceous	Cody shale	1,365	Coal beds, shales, interbedded sandstones, and a few thin nodular limestones; many beds fossiliferous
	Frontier	2,750	Tan sandstones with some interbedded shales; many fossiliferous beds
	Mowry shale	1,070	Siliceous shales, salt-and-pepper sandstone, porcellanite, and bentonite beds
	Thermopolis shale	318	Black shale and argillaceous sandstone
Lower Cretaceous	Cloverly	240–365	Variegated shales and clays with sparkly quartz sandstones and gray lithographic limestones
Upper Jurassic	Stump sandstone	350±	Greenish sandstones with some interbedded siltstone and shale; probably contains glauconite
Middle Jurassic	Twin Creek limestone	475±	Gray limestone and shaly limestone with some interbedded gray to buff shales; several fossiliferous zones
Lower Jurassic	Nugget sandstone	150±	Orange, cross-bedded sandstone; prominent cliff-former

STRATIGRAPHIC COLUMN—(*continued*)

Age	*Formation*	*Thickness (Feet)*	*Lithology*
Lower Triassic	Thaynes and Woodside	950±	Red shales and siltstones with several gray limestone beds
	Dinwoody	235	Tan and gray siltstones, tan sandstone, and limestones; some beds fossiliferous
Permian	Phosphoria	195±	Phosphatic shale, limestone, and chert beds
Pennsylvanian	Tensleep	300±	Alternating sandstones and limestones; sandstone light gray to buff; massive and cross-bedded in places; limestones white to light gray; fine-grained to lithographic
	Amsden	400±	Red shales and siltstone, gray limestone and sandstone; contains Darwin sandstone member
Middle and Upper Mississippian	Brazer limestone	1,000±	Dark gray limestone; finely crystalline to dense; cherty in places
Lower Mississippian	Madison limestone		Gray limestone; fossiliferous, commonly cherty
Devonian	Darby	325±	Brown limestones and dolomites with a few interbedded shales; commonly thin-bedded
Ordovician	Bighorn dolomite	300–400	Buff dolomite; massively bedded; weathers with coarsely pitted and fretted surface; upper 25 or 30 feet white, dense limestone called Leigh member
Upper Cambrian	Boysen	102–181	Gray limestone; oölitic in places; cliff-former
Middle Cambrian	Gros Ventre	539–586	Red and green shales with a little interbedded sandstone; contains prominent limestone member, Death Canyon
Middle Cambrian	Flathead quartzite	240±	Tan and white quartzitic sandstone; conglomeratic near base
Pre-Cambrian			Granite gneiss and pink and white granite; some granite pegmatitic

PRE-CAMBRIAN

There are only a few exposures of pre-Cambrian rock in the northern Gros Ventre Mountains. The most easily accessible of these is along Nowlin Creek, where granite, gneiss, and schist crop out. Although the relationship can not be clearly seen in this area, the granite is probably intrusive into the gneiss and schist.

Very little has been written concerning the pre-Cambrian in this and neighboring areas. St. John[3] states that "the rocks at the western end of the Gros

[3] F. V. Hayden, *Eleventh Annual Report of the U. S. Geol. and Geog. Survey of the Territories Embracing Idaho and Wyoming for 1877* (1879), p. 475.

Ventre Range consist chiefly of much distorted gneissic and schistose ledges." Nelson and Church[4] show a little pre-Cambrian in the Gros Ventre Range on their geologic map and indicate in the stratigraphic column that it consists of gneiss and schist intruded by granite. In the neighboring Teton Range Horberg[5] reports that "The main body of the pre-Cambrian is made up of steeply dipping gneisses and schists which have been intruded by pegmatite, granite and basic dikes, probably in the order named."

Specimens of granite gneiss, white muscovite-biotite granite and pink muscovite granite were collected near Nowlin Creek. The granite is believed to occur as intrusions which cut the gneiss, because in places it is very coarse-grained, almost pegmatitic, and because an intrusive relationship of the granite to the country rock is reported in other parts of the Gros Ventre Range.[6] The principal minerals in the granite gneiss are quartz, microcline, oligoclase, and muscovite with a little zircon, apatite, and garnet and with some alteration to kaolinite, sericite, and chlorite. In the white granite the essential minerals are quartz, oligoclase, microcline, muscovite, and biotite with tourmaline, apatite, titanite, and zircon as accessories. Kaolinite, chlorite, and sericite are the alteration products. The pink granite consists of microcline, oligoclase, quartz, and muscovite. Accessory minerals are zircon and apatite. The alteration products are kaolinite, sericite, and limonite.

CAMBRIAN

General description.—Rocks of the Cambrian system crop out in the southeastern part of the Gros Ventre River area. The Flathead quartzite, Gros Ventre, and Boysen formations are present. The Flathead quartzite is dominantly quartzite and sandstone, commonly quartzitic conglomerate near the base and grading upward into quartzite and then sandstone. Some of the upper sandstones have shale interbedded. The Gros Ventre formation is dominantly green and red shale with a little interbedded sandstone, except for the Death Canyon member, which is dark gray, buff-mottled limestone. The Death Canyon member forms a prominent cliff, above and below which are shale slopes. Flat-pebble conglomerates are characteristic of the upper part of the Gros Ventre. The uppermost formation is the Boysen, which consists of cliff-forming limestones (Fig. 1).

Detailed description.—Outcrops of the Cambrian system in the Gros Ventre River area are almost inaccessible or are not clearly exposed. A partial section was measured along a tributary of Sheep Creek but since it was found to be very much like a more complete Cambrian section measured by Jean Holforty near

[4] Vincent E. Nelson and Victor Church, "Critical Structures of the Gros Ventre and Northern Hoback Ranges, Wyoming," *Jour. Geol.*, Vol. 51, No. 3 (1943), pp. 154 and 145.

[5] Leland Horberg, "The Structural Geology and Physiography of the Teton Pass Area, Wyoming," *Augustana Library Pub. 16*, p. 13. Rock Island, Illinois (1938).

[6] Vincent E. Nelson and Victor Church, *op. cit.*, p. 145.

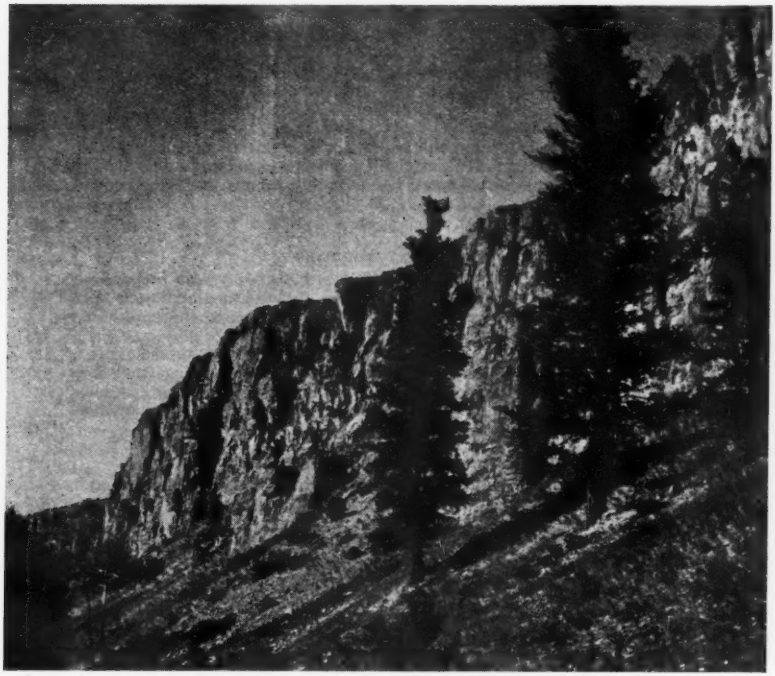


FIG. 1.—Limestone cliffs of Boysen formation exposed near mouth of Sheep Creek.

Granite Falls in the Gros Ventre Range, 16 miles southeast of the Sheep Creek locality, only the Granite Falls section is here described.

BOYSEN FORMATION

Unit	*Thickness (Feet)*
27. Limestone, medium gray on fresh surface; weathers dark gray with tan, sandy mottlings; beds from ½ to 1 foot thick; clay partings	15.2
26. Limestone, gray, weathers dark gray; finely crystalline; beds 2–10 inches thick; forms massive cliff; contains small, flat brachiopods	32.3
25. Limestone, gray, weathers blue-gray; color varies from light gray to dark gray, mottled; mostly massive with some ledges 2 feet thick; contains brachiopods and oölites in streaks; base of oölite zone is 3 feet above the base	11.9
24. Limestone, gray, weathers purplish; thin-bedded with clay partings; crinkly, irregular bedding surfaces	49.2
23. Limestone, gray, weathers bluish gray; massive beds up to 3 feet thick; contains a few interbedded, thin-bedded layers	34.0
22. Limestone, medium gray; weathers tannish; average thickness of beds 2 inches; is thinner-bedded 11.2 feet below top and near base; contains calcite crystals and is coarsely crystalline; contains oölites near top	38.1
Total thickness of Boysen limestone	180.7

GROS VENTRE FORMATION

Unit	*Thickness (Feet)*
21. Limestone, gray, weathers tannish; massive beds 2 feet thick; finely crystalline; contains solution cavities	35.0
20. Limestone, gray, weathers medium gray; has sandy or shaly partings; sub-lithographic, contains some calcite crystals	15.0
19. Limestone, sandy shale and shale; limestone is platy; shale is greenish gray	32.0
18. Shale, black-green, weathers tannish; contains a few limonitic, sandy, rusty weathering zones; thin-bedded; fragments of trilobites, but rock is too much jointed to contain good specimens	24.5
17. Covered; probably shale	25.0±
DEATH CANYON MEMBER	
16. Limestone, dark gray to black; weathers gray to dark bluish gray with brownish or rusty-mottled streaks and patches; finely crystalline to sub-lithographic; contains some calcite veins; thin-bedded, beds ½–5 inches in thickness; average thickness about 2½ inches; cliff-former; cliffs weathered rounded and rather pitted	175.0
15. Covered, probably shale; in one place appears to be olive-green, paper-thin shale	82.3
14. Limestone, dark gray to black, weathers blue-gray with brownish mottlings; mottlings are very sandy; contains sandy lenses and calcite veins; beds are 2–12 inches thick, averaging 6 inches; finely crystalline to sub-lithographic; cliff-former; weathers more angularly than cliffs above	111.3
LOWER PART OF GROS VENTRE FORMATION	
13. Sandstone, yellow-tan; beds 6 inches to 2 feet thick; very calcareous; may contain poorly preserved brachiopods; weathers into angular blocks and slabs	13.0
12. Covered, probably shale	7.3
11. Shale, black, fissile; contains poorly preserved trilobites and worm borings	2.6
10. Sandstone, red-brown, weathers tan; micaceous; may be arkosic; massive, very resistant; weathers with rounded edges; no fossils	1.3
9. Sandstone and shale interbedded; shales are grayish, weather rusty; both are friable and fissile; sandstone beds are reddish brown and 1–8 inches thick	4.0
8. Shale, green friable; no fossils	2.5
7. Shale, green, very micaceous or chloritic; fissile, weathers badly but not as much as unit 5; contains worm borings and poorly preserved trilobites	1.2
6. Shale, red, almost purple; friable; apparently hematitic	1.8
5. Shale and sandstone; shale is green and micaceous or chloritic; much weathered and friable; does not split along even planes; contains many rusty-colored weathered zones; inarticulate brachiopods, many worm borings and a few trilobites; beds so weathered that fossils are poorly preserved, a few ½-inch lenses of black shale which are not as much weathered as the green shale; 3½ feet above base of unit is 1-inch bed of hard, resistant, reddish sandstone, containing no fossils; 5 feet above base of unit is another 1-inch sandstone, reddish brown, highly micaceous, and no fossils; 6½ feet above base of unit is hard, red sandstone, 1½–2 inches thick and more resistant than lower two	10.3
4. Shale, black, weathers tan or rusty; varying amounts of mica; very thin-bedded and fissile; small inarticulate brachiopods, small trilobites up to ¼ inch in size, tails of larger trilobites, worm borings? and several unidentified markings or fossils; weathered rusty-colored zones about every 3 inches vertically; also contains peculiar colonies of algae?	2.0
3. Shale, green, weathers green with brown patches; much mica or chlorite; does not split easily along planes; may contain inarticulate brachiopods; only a little exposed in creek	.2
2. Covered, probably shale	40.0±
Total thickness of Gros Ventre formation	586.3±
FLATHEAD FORMATION	
1. Quartzite, sandy in thin lenses; white to light gray, weathers buff to tan; coarse-grained; fractures easily in several directions along non-parallel planes; cross-bedded; beds 6 inches to 3 feet thick, but even massive beds may lense out entirely in 20 feet horizontal distance; sand grains are well rounded and apparently pure quartz; higher in section quartzite weathers reddish in spots; near top of section appears grayer and weathers darker gray; grades horizontally from coarse-grained to fine-grained (Only upper part of Flathead exposed)	86
Total thickness of Cambrian measured	853 +

Another section was measured by Holforty about 15 miles west of the Sheep Creek section on Glory Mountain in the Teton Range. For comparison, this section is also described.

BOYSEN FORMATION

Unit		*Thickness (Feet)*
11. Covered; small amount of thin-bedded limestone at top		20
10. Limestone, finely crystalline to coarsely crystalline; light gray to variegated on fresh surface; weathers gray to brown, pinkish, yellow, and purplish; contains calcite crystals in places, with some interbedded soft, yellow, calcareous shales; weathers with some rusty mottled patches and contains fucoids and poor trilobite remains; fossils scarce; limestone is oölitic in places; unit very thin-bedded for most part; beds 1–4 inches thick		82.1
f. Limestone; like sub-unit (e) but no pebbles and no black calcite crystals	14.7	
e. Limestone, like Death Canyon limestone; has rusty-mottled patches and irregular bedding surfaces; contains some limestone; pebbles near base of unit; pebbles rounded and composed of calcite crystals which are dark gray to black; limestone is massive-bedded, dark gray	16.2	
d. Limestone, gray, weathers white, finely crystalline; massive	6.6	
c. Limestone and shale; massive ledges of oölitic limestone with a few very thin calcareous gray shales at top	11.8	
b. Limestone, thin-bedded, ¼ inch thick; small oölites	11.4	
a. Limestone, fine to coarse; interbedded with some soft yellow calcareous shales	21.4	
Total thickness of Boysen formation		102.1

GROS VENTRE FORMATION

9. Shale, gray-green, paper thin; weathers light gray, apparently contains no fossils; contains a few ledges of buff shaly sandstones which weather yellow-white; a few ledges of a flat-pebble conglomerate composed of limestone pebbles in limestone cement; upper ledges have more shaly cement; also contains a few ledges of light gray limestone weathering white to gray; limestone is sub-lithographic; first ledge of pebble conglomerate in limestone cement is 57 feet above base of unit; ledge is about 2 inches thick; second ledge of conglomerate in calcareous to shaly cement is 68 feet above base; ledge is 4 inches thick upper 8 feet of unit is gray-green shale interbedded with some conglomerate of limestone pebbles and a few 1- to 2-inch ledges of light gray limestone		78.0
8. Shale and limestone; gray-green shale and dark gray finely crystalline limestone which weathers medium gray to buff		29.7

DEATH CANYON MEMBER

7. Limestone, medium gray to dark gray on fresh surface, weathers dark gray, with rusty and sandy-colored mottled spots; sub-lithographic to coarsely crystalline; beds 1 inch to 2 feet thick, average 4 or 5 inches; locally may contain a few limestone pebbles; contains calcite crystals; contains a few worm? trails		222.4
f. Limestone; contains exceptional amount of calcite crystals; coarsely crystalline	32.8	
e. Limestone, very limonitic, with shale intervals	22.8	
d. Limestone, dark gray, weathers buff; regular bedding surfaces	29.2	
c. Limestone	29.8	
b. Limestone, brecciated and somewhat fragmental	9.1	
a. Limestone like above	98.7	
6. Shales, gray-green to black, weather light gray-green; very thin-bedded, rusty-stained in places; many trilobite and brachiopod remains		14.0
5. Limestone, dark gray to light gray, weathers medium gray to buff and tan; irregular mottlings and a few shale and sandy partings; bedding surfaces and weathered surfaces very irregular; limestone is finely crystalline		59.9

LOWER PART OF THE GROS VENTRE FORMATION

4. Sandstone and shale; sandstone at base; tan, weathers buff; fine-grained; thin-bedded; overlain by shale; shale overlain by sandstone, gray and fine-grained; weathers whitish; both sandstones have calcareous cement		30.3
3. Partly covered; partly green shale, glauconitic; shale is fissile to friable and highly weathered in places; weathers gray-green with limonitic mottlings; contains worm tubes and brachiopods		26.2

Unit		*Thickness (Feet)*
2. Shales and sandstone interbedded; shales green, glauconitic, or chloritic and glistening; highly weathered, fissile to friable; red shales are hematitic, very sandy and oölitic in places; weather dark red to purplish and are more consolidated than Granite Creek red shales; some yellowish limonitic shales very highly weathered and friable; sandstones, hematitic, dark red on fresh surface and weather dark red to purple; form massive ledges 2 feet thick; few shaly gray-green and chloritic sandstones; very thin-bedded; a few tan sandstones, brown on fresh surface, fine-grained; beds 1 foot thick; massive ledges of sandstone, dark green and glistening on fresh surface; weather black-green		77.9
j. Sandstone, hematitic; separated from green sandstone by thin shale	1.5	
i. Sandstone, dark green	0.5	
h. Shale, green and red	4.7	
g. Sandstone, dark green	2.5	
f. Shale, hematitic, oölitic and green; friable	5.0	
e. Sandstone, red, hematitic, massive	1.5	
d. Shale; interbedded yellow limonitic, red hematitic, and green shale	12.6	
c. Sandstone, red; hematitic; massive	1.5	
b. Shale, red and green; sandy and friable; highly weathered and grading into thin-bedded shaly sandstone	19.4	
a. Shale and sandstone; gray-green shale; tan and red-brown sandstones interbedded; shale is very friable	28.7	
Total thickness of Gros Ventre formation		538.4
FLATHEAD QUARTZITE		
1. f. Sandstone; whitish on fresh surface, weathers dark gray to brown; very fine-grained	31.9	
e. Sandstone; dark gray with hematitic and limonitic streaks; fine-grained and cross-bedded; 2-inch shale bed about 30.3 feet below top of unit	42.3	
d. Sandstone; fine-grained; gray-tan on fresh surface, weathers gray-brown; weathers with small limonitic specks on surface	12.4	
c. Sandstone, medium-grained with a few lenses of coarse quartz grains; lenses not continuous; white to buff on fresh surface, weathers dark tan to red-brown	88.0	
b. Quartzite, fine-grained, grading into sandy phase	14.9	
a. Conglomerate, basal; white to tan on fresh surface, weathers tan or buff; quartzitic; composed of white quartz grains, sub-angular to rounded; largest grains $\frac{1}{4}$–$\frac{3}{4}$ inch in diameter; beds massive, 1–3 feet thick; breaks into angular blocks along fractures; fractures easily; cross-bedded	50.0	
Total thickness of Flathead quartzite		239.5
Total thickness of Cambrian		880

On Sheep Creek only the upper part of the Gros Ventre formation and the Boysen could be measured. The Flathead quartzite is present, but not well enough exposed to obtain a section. The Boysen is at least 162 feet thick, thus corresponding more closely in thickness with the Granite Falls section (180 feet) than with the Glory Mountain section (102 feet). Also, lithologically it is more like the Granite Falls section. The limestones of the Boysen on Sheep and Granite creeks have clay partings, contain little or no shale, are cliff-makers, have many fossils, are platy because of thin bedding and brittleness, and commonly have a white to purple cast. In contrast, the Boysen on Glory Mountain has no clay partings, is a poor cliff-maker because of shaly intervals and shaly limestone, contains few fossils, and is generally gray to brown.

The Death Canyon member on both Glory Mountain and at Granite Falls is separated into two limestone units by a thin shale unit. On Glory Mountain the

shale is so thin that the Death Canyon ordinarily forms one prominent cliff, but in the Granite Creek area this shale has thickened so that the Death Canyon limestone forms two prominent cliffs with a shale slope between.

Terminology and correlation.—The confusion in Rocky Mountain Cambrian terminology is well known to students of the subject. It is not the purpose of this paper to correct the situation, but only to show the relationship of the new sections to those previously measured.

The lowest unit of the Cambrian section in western Wyoming is a formation consisting mainly of quartzite or quartzitic sandstone and sandstone. This group of beds was originally named the Flathead quartzite by Peale.[7] It has since been referred to in Wyoming and Montana as the Flathead formation, the Flathead sandstone, and the Flathead sandstone member. In this paper the original term Flathead quartzite is used.

Overlying the Flathead quartzite is a series of shales containing a prominent limestone member. The strata were named the Gros Ventre formation by Blackwelder.[8] The type section was measured on Double Top Peak in the Gros Ventre Range. When Miller[9] measured the Cambrian section in Death Canyon in the Teton Range, he recognized the Gros Ventre formation and named the prominent limestone unit the Death Canyon member of the Gros Ventre formation. The Death Canyon member is both overlain and underlain by shales which have sometimes been referred to as the lower shale member and the upper shale member. However, when Fenton and Fenton[10] remeasured the Death Canyon section, they referred to the Death Canyon member as the Death Canyon facies, and the shales below as the Wolsey formation (a term from the Little Belt Mountains, Montana), and the upper shale zone as the Lower Maurice formation (from a section on Bear Tooth Butte, Montana), and did not retain the name Gros Ventre. The present writer, believing that the term Gros Ventre has a definite meaning in this area and that the Death Canyon member is an easily recognized unit, uses these names. However, it is realized that the Wolsey shale as described by Deiss[11] in Yellowstone Park is probably equivalent to the lower Gros Ventre shales. The Meagher limestone, a prominent limestone above the Wolsey shale in Montana, seems to be correlative with the Death Canyon member, and the Park shale which overlies the Meagher limestone may be the equivalent of the upper Gros Ventre shales (Fig. 2).

[7] Albert C. Peale, "The Paleozoic Section in the Vicinity of Three Forks, Montana," *Bull. U. S. Geol. Survey 110* (1893), p. 20.

[8] Eliot Blackwelder, "New Geological Formations in Western Wyoming," *Jour. Washington Acad. Sci.*, Vol. 8, No. 13 (1918), p. 418.

[9] Maxwell B. Miller, "Cambrian Stratigraphy of Northwestern Wyoming," *Jour. Geol.*, Vol. 44, No. 2, Pt. 1 (1936), p. 119.

[10] Carroll Lane Fenton and Mildred Adams Fenton, "Pre-Cambrian and Paleozoic Algae," *Bull. Geol. Soc. America*, Vol. 50 (1939), p. 96.

[11] Charles Deiss, "Revision of Type Cambrian Formations and Sections of Montana and Yellowstone National Park," *ibid.*, Vol. 47 (1936), pp. 1320–22.

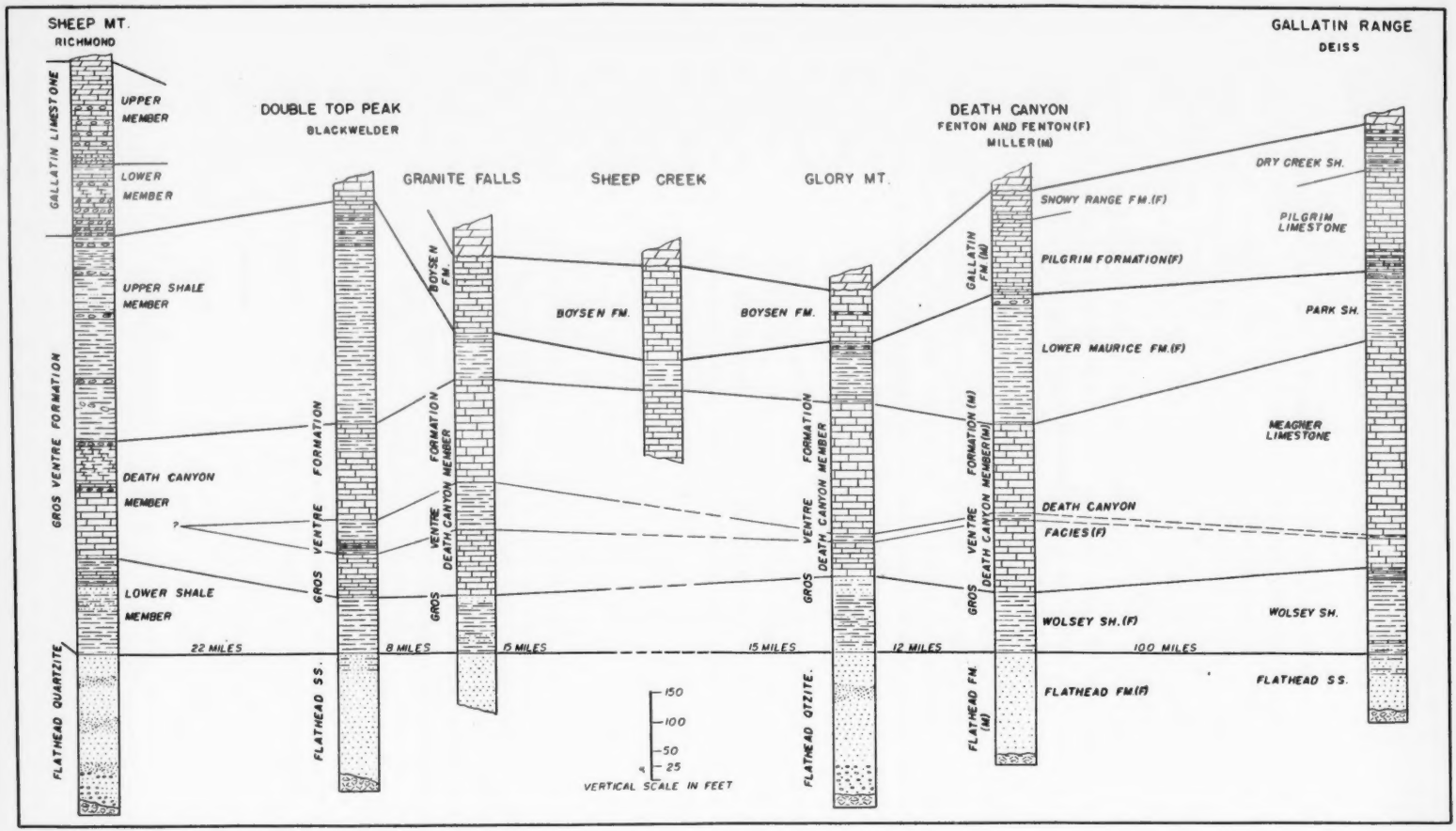


FIG. 2.—Diagram showing correlation of Cambrian formations in northwestern Wyoming.

The Gros Ventre formation is overlain unconformably by a group of limestone beds which were referred to as the Gallatin limestone or Gallatin formation by most early writers. Deiss,[12] who has pointed out that this term should no longer be used, has substituted the name Boysen formation. The type locality for the Boysen is in Wind River Canyon. Although some recent writers have not recognized this change, the name Boysen formation is used for the uppermost Cambrian formation in this paper because Miller[13] and others have shown that it is

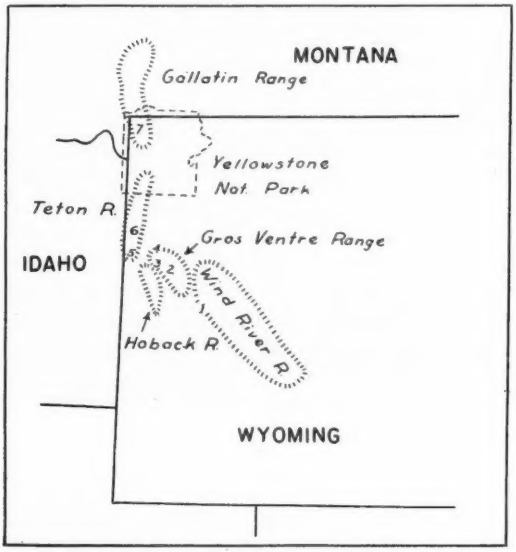


FIG. 3.—Index map showing location of Cambrian stratigraphic sections shown in Figure 2. 1. Sheep Mountain section (Richmond). 2. Double Top Peak section (Blackwelder). 3. Granite Falls section. 4. Sheep Creek section. 5. Glory Mountain section. 6. Death Canyon section (Fenton and Fenton, Miller). 7. Gallatin Range section (Deiss).

correlative with that now called Boysen in the Wind River Canyon. The Boysen of the Gros Ventre and Teton ranges probably also is correlative with the Pilgrim limestone of Yellowstone Park and Montana (Fig. 2). In the Death Canyon section, Fenton and Fenton divided these limestones into the Pilgrim and Snowy Range formations. However, in the sections measured here, no basis was observed for dividing the Boysen.

Figure 2 is intended to show the relationship of the newly presented sections

[12] Charles Deiss, "Cambrian Formations and Sections in Part of the Cordilleran Trough," *Bull. Geol. Soc. America*, Vol. 49 (1938), p. 1104.

[13] Maxwell B. Miller, *op. cit.*, p. 123.

to others, previously measured. The correlations are based on lithologic similarity. An interesting correlation is that of the thin shale separating the limestones of the Death Canyon member. It is found to be present, but very thin, in the northwestern corner of Wyoming. Where traced southward, it thickens continually until it reaches a maximum in the Granite Creek section. It is prominent in the Double Top Peak section, but may either pinch out or perhaps was overlooked on the south in the Sheep Mountain section.

In summary, it may be stated that the sections presented here do show that the Cambrian in the Teton and Gros Ventre ranges is divisible into at least three distinct lithologic units which can be recognized over considerable distances and thus are properly considered formations. The Death Canyon member of the Gros Ventre formation also is a distinct member, which can be traced northward into Montana and eastward as far as the Owl Creek Mountains.[14]

Age and unconformities.—The Flathead quartzite is everywhere unconformable on the pre-Cambrian. Paleontological evidence indicates that it is Middle Cambrian in age.[15] The Gros Ventre formation is probably also Middle Cambrian although there is some uncertainty among workers about the position of the boundary between the Middle and Upper Cambrian; therefore, some of the Gros Ventre might be Upper Cambrian. Miller[16] found an erosional disconformity at the top of the Gros Ventre formation in Death Canyon. The varying thickness of the Upper Gros Ventre shale as compared with the remarkably uniform thickness of the Death Canyon member and lower shale may be due to an unconformity at this position (Fig. 2).

ORDOVICIAN

Description.—The Bighorn dolomite overlies the Boysen formation unconformably. It crops out only in the southwestern part of the Gros Ventre River area near Sheep Creek and in the vicinity of Sheep Mountain. In the Sheep Mountain region it occurs in the massive cliffs like those characteristic of the Bighorn in other areas. Near Sheep Creek the massiveness of the formation is not so apparent, and it is much fractured by faulting (Fig. 4).

The exposures near Sheep Mountain were seen only from a distance, but those on Sheep Creek were examined closely. However, the complete section is not exposed. Here, as elsewhere, the Bighorn consists largely of massively bedded, buff dolomite which weathers with a characteristic "coarsely pitted and fretted surface."[17] As the base of the formation was not exposed it could not be determined whether or not a basal sandstone such as occurs in the Wind River Mountains (the Lander sandstone) was present. On Glory Mountain in the Teton

[14] Maxwell B. Miller, *op. cit.*, p. 120.

[15] *Ibid.*, p. 142.

[16] *Ibid.*, p. 129.

[17] Eliot Blackwelder, "Origin of the Bighorn Dolomite of Wyoming," *Bull. Geol. Soc. America*, Vol. 24 (1913), p. 624.

Range, no definite sandstone member is present, but the dolomite is sandy near the base.

The Leigh member of the Bighorn, which is described by Blackwelder[18] as "being characterized by thin, dense and brittle flaggy strata with smooth milk-white surfaces," comprises the upper 25 or 30 feet of the formation. The Leigh member is exposed north of Sheep Creek.

In the type locality the Bighorn dolomite is about 300 feet thick. Horberg[19]

FIG. 4.—Bighorn dolomite north of Sheep Creek where one of the Sheep Creek faults cuts across the formation.

gives a thickness of 340–385 feet for it in the Teton Range, and it is estimated to be 300–400 feet thick in the Sheep Creek area. Farther northeast in Shoshone Canyon it is 450 feet thick.[20]

Distribution and age.—The Bighorn dolomite was originally described by Darton[21] on the eastern slope of the Bighorn Mountains. Other workers applied the name to strata resembling it over most of Wyoming and in Utah, Idaho, and Montana. It is not present in southeastern Wyoming.[22] Blackwelder studied the formation in considerable detail in the Gros Ventre and Teton ranges.

The age of the Bighorn, at least in the Gros Ventre and Teton ranges is uncertain. In the type locality, numerous fossils were found, particularly in the upper

[18] Eliot Blackwelder, *op. cit.* (1918), p. 419.

[19] Leland Horberg, *op. cit.*, p. 12.

[20] G. D. Johnson, "Geology of the Mountain Uplift Transected by Shoshone Canyon, Wyoming," *Jour. Geol.*, Vol. 42, No. 8 (1934), p. 817.

[21] N. H. Darton, "Comparison of the Stratigraphy of the Black Hills, Bighorn Mountains and Rocky Mountain Front Range," *Bull. Geol. Soc. America*, Vol. 15 (1904), p. 304.

[22] Eliot Blackwelder, *op. cit.* (1913), p. 624.

part of the formation, which indicate that it is Ordovician.[23] The study of fossils from the Wind River Range indicates that the lower part (Lander sandstone) is Upper Ordovician.[24] Miller also considers the upper part of the formation to be Upper Ordovician.[25] Blackwelder[26] collected a small fauna from the Bighorn in the Gros Ventre Range which was considered Upper Ordovician by Ulrich,[27] but placed in the Middle Silurian by Weller and Kindle.[28] No fossils were collected from the Bighorn in the Sheep Creek area as only a few poorly preserved, unidentifiable fossil fragments were observed. On Glory Mountain in the Teton Range a few fish remains were recently discovered in the Leigh member of the Bighorn. According to Gregory,[29] they appear to be arthrodire plates. The only arthrodires known which may be Silurian are a very primitive group from the Upper Silurian. Since the Glory Mountain fish plates do not resemble those of the primitive Silurian group, Gregory believes that they are probably Devonian. Thus, it seems that some of the Bighorn may be Devonian in age and it is possible that part of it may even be Silurian.

Unfortunately, fossils are very scarce and poorly preserved in the Bighorn. However, the age of this formation in the Gros Ventre and Teton ranges can not be determined until more are found. The present information suggests that either the formation called Bighorn in the Gros Ventre and Teton ranges is a different formation from the type Bighorn; or that the so-called Bighorn in western Wyoming may include more than one formation and that only part of the strata are equivalent to the Bighorn formation farther east.

SILURIAN

Strata of definite Silurian age have not been recognized in western Wyoming. However, as pointed out previously, part of the Bighorn formation may be Silurian. The fact that considerable thicknesses of Silurian rocks occur in northern Utah and southeastern Idaho gives further reason to suspect that the Silurian may be represented in western Wyoming.

DEVONIAN

General description.—The Devonian is represented by the Darby formation which overlies the Bighorn dolomite. In the northern Gros Ventre Mountains it crops out along Sheep Creek, in the high country around Sheep Mountain and along the upper part of Flat Creek. Well exposed sections of the Darby formation

[23] A. K. Miller, "The Age and Correlation of the Bighorn Formation of Northwestern United States," *Amer. Jour. Sci.*, 5th Ser., Vol. 20 (1930), p. 197.

[24] *Ibid.*, p. 198.

[25] *Ibid.*, p. 209.

[26] Eliot Blackwelder, *op. cit.* (1913).

[27] *Ibid.* (1913), p. 610.

[28] *Ibid.*, p. 610.

[29] J. T. Gregory, personal communication (1947).

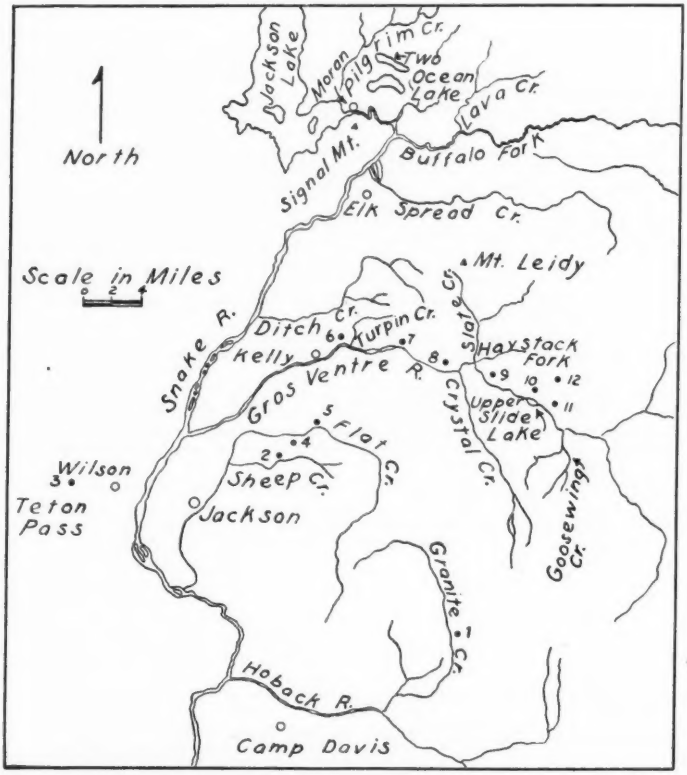


FIG. 5.—Index map showing location of stratigraphic sections. 1. Cambrian and Devonian sections on Granite Creek. 2. Cambrian section on Sheep Creek. 3. Cambrian and Devonian sections on Glory Mountain Teton Range. 4. Amsden section north of Sheep Creek. 5. Tensleep and Phosphoria sections on north side of Flat Creek. 6. Brazer section on Gros Ventre River. 7. Twin Creek, Stump and Cloverly sections on Gros Ventre River. 8. Thermopolis section and lower two units of Mowry section in Red Hills. 9. Mowry section on Gros Ventre River. 10. Frontier section on northeast side of Upper Slide Lake. 11. Cody section in Cole Hollow. 12. Mesaverde section north of Cole Hollow.

are difficult to find, as it commonly forms covered slopes between the more resistant Madison and Bighorn formations. It consists mainly of brown limestones and dolomites with a few interbedded shales. It is ordinarily thin-bedded, in many places porous and cavernous, and commonly has a petroliferous odor. It is probably about 325 feet thick.

Detailed description.—Although no complete section was measured in the northern Gros Ventre area, two detailed sections were measured by Jean Holforty at near-by localities. On Granite Creek in the Gros Ventre Range a section was obtained which has the following description.

Unit	*Thickness (Feet)*
48. Shale, yellowish green; thin-bedded	Few feet
47. Limestone, brownish; very thin-bedded	est. 10
46. Limestone, brown; medium-grained; massive beds; very deeply pitted on weathered surface	est. 75
45. Dolomite, light gray, weathers yellowish; fine-grained; very thin, shaly bedding	14
44. Limestone, brown, weathers tan; fine- to medium-grained; one massive bed	0.9
43. Dolomite, light gray, weathers tan; very sandy; a few shaly beds in unit; beds ½–1 foot thick	12.5
42. Limestone, gray, weathers tan; sandy; oölitic; thin-bedded	2.7
41. Dolomite, grayish, weathers tan; sandy; very coarse; massive beds; irregular bedding surface	2.8
40. Covered; seems to be thin-bedded dolomite at top	6.0
39. Limestone, brown, weathers gray to tan; fine-grained; one massive bed; very deeply pitted weathered surface near top	9.0
38. Dolomite, gray, weathers tan; fine-grained; thin-bedded	7.2
37. Limestone, gray-tan, weathers tan; fine-grained; sandy; beds about 2½ feet thick	12.0
36. Covered	5.0
35. Limestone; much like unit 33; pitted weathered surface	3.0
34. Dolomite, gray, weathers tan to light gray; fine-grained; hard; conchoidal fracture	3.5
33. Limestone, brown, weathers grayish brown; medium-grained; slightly pitted weathered surface; massive beds; 11 feet above base of unit is 1.4 feet of more thinly bedded, darker gray, finer-grained limestone	20.3
32. Limestone, light tan-gray, weathers tan; sandy; fine-grained; thin-bedded; beds are ½–4 inches thick; unit partly covered	3.6
31. Limestone, brown, weathers grayish brown; medium-grained; massive beds; contains many oblong cavities on weathered surface which are not filled with calcite crystals; cavities parallel with bedding	23.3
30. Limestone, light gray; fine-grained	0.9
29. Shale, gray-green	0.3
28. Dolomite, gray; dense; thin-bedded	0.8
27. Dolomite, gray with green shaly zones	1.1
26. Like unit 24	0.8
25. Shale, brownish green; thin-bedded	0.2
24. Dolomite, brownish gray; thin-bedded; finely laminated and wavy bedding planes	1.3
23. Shale, gray-green	0.3
22. Dolomite, gray weathers bluish gray to brown; fine-grained; very hard; conchoidal fracture in some of rock near base of unit; massive ledges at base of unit; more thin-bedded near top	6.5
21. Limestone, light gray-tan, weathers tan; sandy; coarse-grained; only two beds in unit	2.7
20. Limestone, dark brown to black, weathers brown in ·-foot massive ledge at base and dark gray above; fine-grained in massive ledge at base; very-fine-grained to hard and dense near top; top part has splintery fracture; topmost bedding surface very irregular and deeply pitted; cavities lined with calcite crystals	5.0
19. Dolomite, light tan-gray, weathers tan; sandy; fine-grained; beds 6 inches thick	2.1
18. Dolomite, gray, weathers light tan-gray; soft, sandy; fine- to medium-grained; weathers in rounded cliffs; beds about 8 inches thick	1.9
17. Dolomite, gray-green; very thin-bedded; shaly; roughly rectangular fracture; nodular near top; unit partly covered	3.3
16. Limestone, light gray-brown, weathers tan; fine-grained; contains tiny cavities on weathered surface; calcite fillings; irregular bedding surfaces; beds about 1 inch thick	7.6
15. Limestone, gray-tan, weathers brownish; fine-grained; contains tiny laminated parts; one massive ledge	1.1
14. Sandstone or very sandy dolomite, light tan-gray; fine-grained; one massive ledge	0.7
13. Dolomite, like unit 11; weathers rusty in places; a few calcareous and shaly suture-like partings	3.0
12. Limestone, brown, weathers brownish gray; fine-grained; one massive ledge	2.7
11. Dolomite, light gray, weathers light gray to yellow; very hard and dense; rather massive	3.6
10. Partially covered; dolomite, gray, weathers buff; medium-grained; beds thin to 1 inch thick; limonitic stain and peculiar markings on bedding surfaces; slabby	9.7

Unit	Thickness (Feet)
9. Limestone, dark brown, weathers grayish brown; fine-grained; fairly thin-bedded although appears massive; pitted on weathered surface near base	5.0
8. Shale, gray; thin-bedded; nodular; dolomitic	0.7
7. Limestone, dark gray, weathers dark bluish gray to medium gray; sub-lithographic; massive; irregular bedding	11.7
6. Partly covered; seems to contain thin, shaly dolomite	4.0
5. Limestone, dark gray, weathers medium gray; medium-grained; finely laminated; slabby; beds 1–10 inches thick; fossil fragments (?)	4.7
4. Limestone, gray-brown, weathers brown; fine-grained; massive beds; minute cavities on weathered surface containing calcite crystals	6.2
3. Dolomite, dark gray, weathers light gray; fine-grained; thin-bedded	3.5
2. Dolomite, gray-brown, weathers brown; fine-grained; slight petroliferous odor; beds 2–4 inches thick	6.0
1. Dolomite, gray, weathers sandy colored; fine-grained and nodular; thin-bedded; beds ½–1 inch thick; unit partly covered	4.0
Total thickness measured	312.2

On Glory Mountain, in the Teton Range, about 15 miles west of the Sheep Creek outcrops, the following described section was obtained by Holforty.

Unit	Thickness (Feet)
28. Limestone, dense; variegated in color—yellow, pink, green; somewhat sandy; thin-bedded with very irregular bedding	24.0
27. Covered; probably contains thin-bedded yellow shale	55.0
26. Limestone, grayish brown; dense; massive to thin-bedded; irregular bedding; many cavities or solution pits on weathered surfaces; brecciated at top	17.5
25. Covered; top 3½ inches are shale, yellow-green but somewhat variegated in color; thin-bedded with very irregular bedding surfaces	8.0
24. Limestone, yellow and somewhat variegated in color; very irregular bedding; beds 1–5 inches thick	6.0
23. Covered	5.0
22. Limestone, light gray to dark gray, weathers gray to tan; dense; thin-bedded; beds ¼–2 inches thick	20.0
21. Limestone, dark gray to brown, weathers dark brown; fine-grained; beds 3 inches thick; weathers in angular blocks; strong petroliferous odor	3.0
20. Limestone, buff, weathers yellow; somewhat variegated in color; dense, sandy; thin-bedded; slightly irregularly weathered	25.0
19. Limestone, variegated in color—white to buff and red; dense; irregular bedding surfaces; pitted weathered surface	28.0
18. Limestone, brown	4.5
17. Limestone, variegated in color; very irregular bedding surfaces and many openings or pitted surfaces; beds 1–4 inches thick	5.0
16. Limestone, medium gray to brown; beds ½–4 inches thick; contains some chert and geodes with calcite fillings; weathers buff; most geodes in lower 15 feet	60.0
15. Covered	6.0
14. Shale, yellow-brown; thin-bedded	1.0
13. Limestone, light gray, weathers dark gray; fine-grained; massive beds	4.0
12. Limestone, black, weathers gray; thin-bedded; dense	1.0
11. Limestone, brown, weathers gray-brown; dense; massive to thin-bedded; bedding plane surfaces irregular in places; 2-foot greenish yellow, thin-bedded shale 5 feet above base of unit	10.0
10. Covered	10.0
9. Limestone, gray, weathers whitish to yellow; beds 2 inches thick; slightly irregular bedding surfaces	1.5
8. Limestone, black, weathers dark gray; thin-bedded	1.0
7. Limestone, brown; thin-bedded; cavernous	5.0
6. Limestone, brownish gray; dense; very irregular bedding surfaces and many cavities; beds about 10 inches thick; strong petroliferous odor; middle 5 feet is more massive, darker gray, and has more regular bedding surfaces	15.0

Unit	*Thickness (Feet)*
5. Limestone, buff, weathers tan to brown; sandy; fine-grained	3.0
4. Shale, brownish gray; thin-bedded; sandy and soft with talc-like feel	0.5
3. Limestone, dark gray to black, weathers bluish white; dense	4.0
2. Limestone, brownish gray, weathers brownish gray; many solution cavities; cherty	7.5
1. Partially covered; limestone, medium gray, weathers light gray to buff; fine-grained; cherty in places; contains chert nodules; fairly thin-bedded; upper 2 inches dense, light gray limestone, weathers whitish	5.0
Total thickness	335.5

The Glory Mountain and Granite Creek sections differ considerably. On Glory Mountain, the Darby is mostly made up of gray to brown limestones with a few shale intervals, but on Granite Creek, the Darby is mainly dolomite with a few limestones. No detailed correlation between the two sections could be worked out. The Granite Creek section resembles Blackwelder's Sheep Mountain section[30] in that it contains numerous dolomite beds, but Blackwelder's section contains more shale.

Blackwelder[31] states that the Darby formation is disconformable on the Leigh member, or in some places on the massive member of the Bighorn dolomite. In the two sections presented here, no definite disconformity was recognized, and the contact seemed to be somewhat gradational.

Distribution and age.—The Darby formation was named by Blackwelder[32] from Darby Creek on the west side of the Teton Range. He states that the formation is present over most of northwestern Wyoming and that it has been recognized in a modified condition as far southwest as the Wasatch Range. He believes that the formation is equivalent to Peale's Three Forks shale (Montana) plus the upper part of the Jefferson limestone.

More recent work indicates that the Darby is probably not equivalent to the Three Forks.[33]

The Darby formation is approximately 330 feet thick in the Teton and Gros Ventre areas. It thins in a short distance east and pinches out on the east side of the Wind River Mountains.[34] It thickens not far west and southwest. In the Snake River Canyon on the southwest it is more than 500 feet thick, and in southeastern Idaho Devonian rocks reach a thickness of more than 1100 feet.[35] In southwestern Wyoming, Devonian rocks at Labarge Mountain are more than

[30] Eliot Blackwelder, *op. cit.* (1918) p. 417.

[31] *Ibid.*, p. 421.

[32] *Ibid.*, p. 420.

[33] G. Arthur Cooper, "Correlation of the Devonian Sedimentary Formations of North America," *Bull. Geol. Soc. America*, Vol. 53, No. 12, Pt. 1 (1942), p. 1754.

[34] E. B. Branson and C. C. Branson, "Geology of the Wind River Mountains, Wyoming," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, No. 1 (1941), p. 129.

[35] Clyde P. Ross, "Geology and Ore Deposits of the Bayhorse Region, Custer County, Idaho," *U. S. Geol. Survey Bull. 877* (1937), p. 26.

1,000 feet thick.[36] Love[37] recognized the Darby on the northeast along the southern margin of the Absaroka Range and found that the thickness was variable. One section in this area is 146 feet thick. Devonian rocks in Montana vary considerably in thickness, being more than 100 feet thick in the Phillipsburg Quadrangle.[38] However, their relationship to the Darby has not been studied. Few fossils have been found in the Darby, but on the basis of the information available, it is considered Devonian in age.[39]

MISSISSIPPIAN

General description.—The Mississippian system in the Gros Ventre River area is represented by the Madison and Brazer limestones. Together they are the most prominent cliff-formers in the area. They cap Sheep Mountain and other high peaks and ridges in that vicinity. They are exposed more than 7 miles on the spur northwest from Sheep Mountain. The Mississippian also crops out on Blacktail Butte where the beds are brought up by a fault and stand almost vertically. The Madison and Brazer together are more than 1,000 feet thick.

MADISON LIMESTONE

The Madison limestone which overlies the Devonian Darby formation is typically gray in color in contrast to the brownish Darby limestones. The limestone was originally named by Peale[40] from the Madison Range in the Three Forks Quadrangle in Montana. It has since been recognized in Montana, Wyoming, Idaho, and northern Utah.

In some places the Madison contains considerable chert. It is the only Paleozoic limestone in the area being described which contains abundant fossils. It can be differentiated from the Bighorn and Darby formations by the numerous brachiopods and small cup corals which it contains. The Madison limestone is generally considered lower Mississippian in age.

BRAZER LIMESTONE

The Madison limestone is overlain by the Brazer limestone. The Brazer in northern Utah was named by Richardson.[41] It has been recognized in north-

[36] Edward M. Kindle, "The Fauna and Stratigraphy of the Jefferson Limestone in the Northern Rocky Mountain Region," *Bull. Amer. Paleon.*, Vol. 4, No. 20 (1908), p. 6.

[37] John David Love, "Geology along the Southern Margin of the Absaroka Range, Wyoming," *Geol. Soc. America Spec. Paper 20* (1939), p. 121.

[38] Arthur Bevan, "Rocky Mountain Front in Montana," *Bull. Geol. Soc. America*, Vol. 40 (1929), p. 471.

[39] Eliot Blackwelder, *op. cit.* (1918), p. 421.

[40] Albert C. Peale, "The Paleozoic Section in the Vicinity of Three Forks, Montana," *Bull. U. S. Geol. Survey 110* (1893), p. 32.

[41] G. B. Richardson, "The Paleozoic Section in Northern Utah," *Amer. Jour. Sci.*, 4th Ser., Vol. 36 (1913) pp. 407, 413.

eastern Utah, south-central Idaho, and in southwestern Wyoming. Horberg[42] noted it in the Teton Range.

The Brazer is gray, but commonly darker gray than the Madison. It is finely crystalline to dense and is cherty in places. In some localities it is much fractured, and has networks of calcite veinlets. A limestone breccia occurs at the top of the formation in most localities. Near Sheep Creek this breccia is not present, but it is found about 5 miles north along the Gros Ventre River. The Brazer in some places contains compound corals of the *Lithostrotian* ? type. It is considered Middle and Upper Mississippian in age.[43]

The following section of the Brazer was measured on the Gros Ventre River in the NE. ¼ of Sec. 1, T. 42 N., R. 115 W., Teton County, Wyoming, by Harold Wanless and Ruth Bachrach. The lower part of the section was not exposed here.

Unit	*Thickness (Feet)*
12. Limestone, brown-gray; dense to finely crystalline; irregularly brecciated at several levels; black chert and some agate	20.0
11. Agate and sub-rounded limestone pebbles	0.5
10. Limestone breccia, dull gray; fine-grained; agate fragments; black chert; fossil fragments	2.0
9. Limestone rubble, gray; pieces 2 feet by ½ foot; slightly rounded	0.5 to 1
8. Limestone, gray; weathers pink; brecciated; lithographic; some stylolites	0 to 1.5
7. Limestone, gray; weathers pink; oxidized to pink in upper 6 inches; lithographic; even-bedded; interrupted by unconformity	0 to 1.5
6. Shale, red; absent in places because of unconformity	0 to 1.5
5. Limestone, gray with red shale wash	3.5
4. Limestone, light pink; sub-lithographic	3.5
3. Limestone breccia, gray; fragments subangular to angular; ½–6 inches; includes poorly sorted pebbles, darker gray than matrix; finer-grained upward	4.0
2. Limestone, light brown-gray; finely crystalline	1.0
1. Limestone, dull gray; sub-lithographic; dense	15.0
Lower units not exposed	
Total measured	50–55

PENNSYLVANIAN

General description.—The Pennsylvanian system is represented in the Gros Ventre River area by the Amsden and Tensleep formations. There are many exposures near the Gros Ventre River and in the area on the south. The Tensleep, being a resistant formation, caps many high ridges and peaks. The famous Kelly's landslide on the Gros Ventre River occurred in Tensleep and Amsden rocks.

AMSDEN FORMATION

General description.—The Amsden formation was originally described by Darton[44] from exposures of the formation along the Amsden Branch of the Tongue

[42] Leland Horberg, *op. cit.*, p. 16.

[43] Stewart J. Williams and James S. Yolton, "Brazer (Mississippian) and Lower Wells (Pennsylvanian) Section at Dry Lake, Logan Quadrangle, Utah," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, No. 8 (1945), p. 1150.

[44] N. H. Darton, "Comparison of the Stratigraphy of the Black Hills, Bighorn Mountains, and Rocky Mountain Front Range," *Bull. Geol. Soc. America*, Vol. 15 (1904), p. 396.

River, west of Dayton, Wyoming. It has been recognized rather widely in Wyoming and in Montana. Blackwelder,[45] while working in the Gros Ventre Range, recognized in the Amsden a prominent sandstone which he named the Darwin sandstone member.[46]

The Amsden formation and its Darwin sandstone member are present in the Gros Ventre River area, but here the Darwin does not form the basal unit of the Amsden as it does where Blackwelder described it. In the Gros Ventre River area the Darwin is underlain by about 60 feet of thin-bedded, gray and pink limestones, sandstones, and shales. This lower Amsden unit rests on the Brazer formation.

The Darwin sandstone member as seen near Sheep Creek consists of about 97 feet of light gray, cross-bedded, massive sandstone. However, in exposures along the Gros Ventre River it seems to be represented by pink, brick-red, and yellow-brown sandstone with interbedded siltstones. The Darwin sandstone is overlain by 200–300 feet of upper Amsden pink-mottled limestone, red shales, and red siltstones.

Detailed description.—The Amsden section here given was measured by Wanless and Bachrach north of Sheep Creek in the NE. ¼ of Sec. 10, T. 42 N., R. 115 W., Teton County, Wyoming. The top of the Amsden is covered at this locality.

Unit	*Thickness (Feet)*
22. Covered	55
21. Limestone, light brown-gray; sub-lithographic	2
20. Limestone, medium gray; dense to finely crystalline; numerous fossil fragments	3
19. Covered	93
18. Limestone, dark gray; finely crystalline; solution pitted; small gray chert nodules; poorly preserved fossil fragments	1½
17. Sandstone, light gray, weathers brown; hard; calcareous	1
16. Limestone, dull gray; crystalline; many crinoid stem fragments	18
15. Limestone, light yellow-gray; fine-grained; thin-bedded to 6 inches; arenaceous	12
14. Covered	2
13. Limestone, red; impure; argillaceous, arenaceous; thin-bedded	3
12. Shale, maroon to red	11
DARWIN SANDSTONE MEMBER	
11. Sandstone, light gray, weathers buff; strongly cross-bedded	93
10. Sandstone, red; thin-bedded; calcareous	4
LOWER AMSDEN	
9. Limestone, light gray; fine-grained; solution pitted; very massive	11½
8. Shale, dark red; soft; very calcareous	16
7. Limestone, pink to lavender; impure; argillaceous	2½
6. Limestone, light yellow-gray; sub-lithographic; splintery fracture	4½
5. Limestone, dark gray; fine-grained; massive; solution pitted	3½
4. Limestone, light gray; splintery fracture; lithographic	5½
3. Limestone, medium gray; finely crystalline; pitted surfaces; massive	7½
2. Chert, dark gray; uneven surfaces	0 to ¼
1. Unconformity	
Total thickness of Amsden formation	350

[45] Eliot Blackwelder, *op. cit.* (1918), p. 422.

[46] The Darwin sandstone was named from Darwin Peak in the Gros Ventre Mountains, but due to an error in spelling in the publication in which the name was first used it commonly occurs in print as the "Dorwin" sandstone.

Age of Amsden.—The age of the Amsden formation in this region has not been definitely determined. Fossils resembling both Mississippian and Pennsylvanian types have been collected from the lower Amsden beds. The fossil evidence seems to indicate that the Mississippian-Pennsylvanian boundary is near the base of the Darwin sandstone, but no exact contact line can be drawn.

TENSLEEP FORMATION

Description.—The Tensleep formation was originally named by Darton[47] from exposures of the formation on the west side of the Bighorn Mountains in the canyon of Tensleep Creek. In the Gros Ventre River area, it characteristically consists of alternating limestones and sandstones. The sandstones are typically light gray to buff, fine-grained, and massive. They are commonly cross-bedded. The limestones are white to light gray, fine-grained to lithographic and in many places dolomitic.

The following described section was measured by Wanless and Bachrach along Flat Creek, on its north side, in Sec. 1, T. 42 N., R. 115 W., Teton County, Wyoming.

Unit	*Thickness (Feet)*
15. Sandstone, light gray; fine-grained; crystalline, with calcite veins	57
Unconformity	
14. Chert, light gray	1
13. Limestone, white; somewhat chalky; very fine-grained; contains tan chert	11
12. Limestone, light gray, weathers brown; coarsely crystalline; very cherty; calcite veins	6
11. Sandstone, light gray; fine-grained; massive; calcareous; sparkly	61
Unconformity with 1 inch relief	
10. Dolomite, light blue-gray; silty; massive; solution pitted; fucoid-like markings	8
9. Sandstone, buff; calcareous; massive	13
8. Limestone, light gray; dolomitic; fine-grained; massive; geoidal cavities	13
7. Limestone, light gray, weathers white; dolomitic; sub-lithographic; highly jointed	6
6. Sandstone, light gray, weathers red-brown; calcareous; fine-grained; firmly indurated; cross-bedded	22
5. Sandstone, light yellow-gray; calcareous; medium-grained; somewhat friable; prominently banded; somewhat cross-bedded	25
4. Sandstone, light yellow-gray, weathers brown; fine-grained; slightly calcareous; firmly indurated; pronounced vertical jointing	8
3. Sandstone, light yellow-gray; medium- to coarse-grained; calcareous; sparkly; cross-bedded; irregularly laminated	53
2. Covered	12
1. Sandstone, buff; calcareous	2
Total thickness of Tensleep Formation	298

The Tensleep section which is exposed on the Gros Ventre River differs slightly from the foregoing section. It has fewer limestone units interbedded with the sandstones.

Age and correlation.—The Pennsylvanian age of the Tensleep formation has long been recognized. However, few diagnostic fossils have been found to indicate

[47] N. H. Darton, "Comparison of the Stratigraphy of the Black Hills, Bighorn Mountains, and Rocky Mountain Front Range," *Bull. Geol. Soc. America*, Vol. 15 (1904), p. 397.

its position in the Pennsylvanian system. Recent studies of microfossils from the Tensleep by Scott[48] indicate a Des Moines age for the formation in northern Wyoming and show that it is correlative with the Quadrant formation of Montana. The name "Wells formation" has been applied to the Tensleep rocks in this part of Wyoming,[49] but the Wells formation probably includes not only beds equivalent to the Tensleep but also younger Pennsylvanian rocks.[50]

PERMIAN

General description.—The Permian system is represented in the Gros Ventre River area by the Phosphoria formation. It crops out on the north side of Flat Creek and in a long narrow belt which extends from the mouth of the Gros Ventre River canyon southward and eastward. The belt of outcrop crosses the valley of Crystal Creek, then continues southward and crops out in the cliffs bordering the eastern side of Crystal Creek.

In the Gros Ventre and Flat Creek localities, the Phosphoria consists mainly of cherty limestones, and dolomites, phosphatic shales, and thin sandstone and chert beds. The upper part of the formation consists of almost pure chert beds with some cherty limestone which has been called the Rex chert member.

Detailed description.—Blackwelder described the phosphate beds which make up the Phosphoria formation in the Gros Ventre River area as follows.[51]

> Fossils are rare, except obscure pelecypods in the upper part. Being comparatively soft, these strata generally occupy saddles or ravines between ridges of the underlying sandstone and the harder Triassic red sandstone. Good exposures of them are to be found only in cliffs. . . . As usual, the phosphatic portion is near the base and within this portion there are several distinct layers of phosphate rock and phosphatic shale separated by clay shale and limestone. As in the Hoback Range, there are two principal beds of phosphate. The richer bed lies near the base, is between 5 and 7 feet thick, and consists of soft black oolite interspersed with some hard coarse-grained bands and a few seams of brownish phosphatic limestone. In this bed the content of tricalcium phosphate varies between 27 and 80 per cent, and the average content is apparently somewhat more than 50 per cent. The upper phosphate bed lies beneath a massive bed of chert, characterized by peculiar vertical tubular concretions that bear a fancied resemblance to a mass of twisted boiler tubes. This upper phosphatic bed consists largely of black or dark-gray shale with a thin layer of hard pisolitic phosphate rock at the base. The hard layer is less than 6 inches thick, but averages 56 per cent of tricalcium phosphate. The overlying shales are 40 to 45 feet thick, and their phosphate content is but 5 to 15 per cent.

Blackwelder gives a detailed section measured near the mouth of Crystal Creek on the south side of the Gros Ventre River. His section includes 288½ feet of

[48] Harold W. Scott, "Age of the Amsden Formation," *Bull. Geol. Soc. America*, Vol. 56, No. 12, Pt. 2 (1945), p. 1196.

[49] Leland Horberg, *op. cit.*, p. 16.

[50] H. W. Scott, oral communication (1945).

[51] Eliot Blackwelder, "A Reconnaissance of the Phosphate Deposits in Western Wyoming," *U. S. Geol. Survey Bull. 470* (1911), p. 468.

strata, but the upper 150 feet are probably beds included in the Dinwoody formation in this paper. Thus, the Phosphoria is probably about 138 feet thick at this locality.

Lily Marie Krusekopf and Harold Wanless measured the following Phosphoria section on the bluff on the north side of Flat Creek. The lower phosphatic zone mentioned by Blackwelder is represented by units 4 through 11. The upper phosphatic zone is represented by unit 30. Blackwelder's tubular chert concretions which resemble "a mass of twisted boiler tubes" are present in unit 37.

Unit	*Thickness (Feet)*
37. Chert, dark gray to black, deep red iron stains, weathers tan; hackly to brittle beds; beds 1–3 inches thick; minute shale partings; a 4-foot massive zone near middle of unit; beds thicker and more nodular at top; tubular black chert concretions 2–4 inches in diameter and bent about 40° occur just below Dinwoody contact	50.0
36. Chert and shale, black; shale is paper-thin; more chert toward top of unit	3.1
35. Shale, dark gray to black; paper thin layers	9.2
34. Dolomite, black; massive; similar to unit 32	2.5
33. Shale, black; thin-bedded; soft	9.0
32. Dolomite, black; fetid	1.5
31. Shale, black; thin-bedded; soft	2.8
30. Phosphorite and shale; phosphorite in two zones each a few inches thick; not pisolitic; banded; shale between phosphorite zones, black, weathers brown	4.0
29. Dolomite or dolomitic limestone, medium gray, weathers tan; massive; pitted; fossiliferous zone near top; calcite fills large pelecypod (*Pecten*) and gastropod (*Euphemites*) shells; vertical joints; cliff-former; more thinly bedded about 16½ feet above base of unit; darker and finer-grained near top; specimen of *Conularia* found 8 feet from top	40.0
28. Dolomite, light gray with strip of light blue-gray chert nodules 2.5 feet from base; calcite veins and geodes; much fractured	10.3
27. Shale, buff to yellow	5.0
26. Siltstone, weathers tan; siliceous; thin and irregularly bedded; platy	3.0
25. Siltstone, buff, weathers lighter buff; slightly calcareous; string of milky white chert nodules 2.3 feet above base; light blue-gray chert nodules at top; beds 1–2 inches thick at base; more massive near middle of unit	8.2
24. Conglomerate; chert pebbles in sandy matrix	.8
23. Chert breccia, light tan-gray, weathers tan; shaly breaks with scattered chert pebbles; calcite along joint surfaces	11.7
Unconformity; underlying beds pitted and eroded.	
22. Dolomite, medium gray, weathers tan-gray; massive	0–1
21. Chert, light to medium gray with iron stains; consists of flattened chert nodules, poorly cemented	1.0
20. Shale, light gray; greenish gray oval chert nodules in upper part of unit	2.0
19. Shale, greenish brown; soft	5.0
18. Chert and calcite; lower 2 feet of unit thin-bedded and has wavy bands; more massive at top	4.5
17. Dolomite, dark gray; brittle; dense; cherty; slightly petroliferous	1.0
16. Claystone, brown; siliceous; thin-bedded; laminated; a few calcite nodules	5.2
15. Dolomite, dark gray, weathers tan; siliceous; brittle; dense; petroliferous; conchoidal fracture	.6
14. Claystone and dolomite, greenish brown, weathers tan; platy	1.0
13. Limestone, yellow-brown, weathers reddish; iron-stained; dense; siliceous or argillaceous	0.5
12. Dolomite, light to medium gray; dense; conchoidal fracture	0.1
11. Shale, brown; poorly cemented; pisolitic; phosphatic	0.3
10. Phosphorite, green; pisolitic; glauconitic (?)	0.2
9. Shale, green; glauconitic; pisolitic; phosphatic	0.5
8. Limestone; phosphatic	0.3
7. Shale, brownish gray; phosphatic	0.3
6. Phosphorite, brownish gray; weathers bluish; pisolitic	0.2
5. Limestone, light-colored; probably phosphatic; pisolitic; grades into phosphorite	1.3

Unit	*Thickness (Feet)*
4. Phosphorite, weathers bluish white; pisolitic	1.1
3. Chert, light to medium blue-gray, weathers tan; brecciated in lower 2 feet of unit; cavities and veins filled with milky calcite; ledge former	5.5
2. Conglomerate; pebbles ½–2 inches in diameter; quartzite, chert and limestone pebbles in phosphorite matrix	0.6
1. Sandstone; conglomeratic; rounded pebbles of chert, quartzite; matrix similar to Tensleep sandstone below	1.6±
Total thickness of Phosphoria formation	195.9–194.9

Age of Phosphoria formation.—The Phosphoria formation was named by Richards and Mansfield[52] from exposures in southeastern Idaho. It has generally been considered as Permian in age. The economic aspects and distribution of the Phosphoria have been studied in considerable detail, but comparatively little has been done with the fauna. Girty[53] has made some studies of the fauna and on paleontological and stratigraphic evidence favors a Permian age. Branson[54] regards it as both Upper Pennsylvanian and Lower Permian. He believes that there is a gradation from Pennsylvanian to Permian with no stratigraphic break. Miller and Cline,[55] from a study of the cephalopods from the Phosphoria conclude that at least part of the type Phosphoria section is Middle Permian. They suggest that if fossil evidence, such as that presented by the Bransons,[56] indicates that some of the lower Phosphoria beds are of Pennsylvanian age, these beds should be removed from the Phosphoria formation and placed in a separate formation. Frenzel and Mundorff,[57] on the basis of fusulinid and other fossil evidence, concluded that the beds generally called Phosphoria are referable to more than one stage of the Permian. The beds from which they obtained fusulinids in southwestern Montana were near the base of the formation and are of Lower Permian age. The only significant fossil obtained from the Phosphoria in the Gros Ventre area was a specimen of *Conularia kaibabensis* McKee found about eight feet from the top of unit 29. This species occurs in the Middle Permian Kaibab formation in northern Arizona.[58] Thus it seems likely that at least part of the Phosphoria in this area is Middle Permian.

[52] R. W. Richards and G. R. Mansfield, "The Bannock Overthrust," *Jour. Geology*, Vol. 20, No. 8 (1912), pp. 681–89.

[53] G. R. Mansfield and G. H. Girty, "Geography and Geology and Mineral Resources of Part of Southeastern Idaho, with Descriptions of Carboniferous and Triassic Fossils, "*U. S. Geol. Survey Prof. Paper 152* (1927), p. 78.

[54] C. C. Branson, "Paleontology and Stratigraphy of the Phosphoria Formation," *Missouri Univ. Studies*, Vol. 5, No. 2 (1930), p. 5.

[55] A. K. Miller and L. M. Cline, "The Cephalopods of the Phosphoria Formation of Northwestern United States," *Jour. Paleon.*, Vol. 8, No. 3 (1934) p. 285.

[56] C. C. Branson, *op. cit.*, and E. B. Branson, "The Lower Embar of Wyoming and Its Fauna," *Jour. Geology*, Vol. 24, No. 7 (1916), pp. 639–64.

[57] Hugh Frenzel and Maurice Mundorff, "Fusulinidae from the Phosphoria Formation of Montana," *Jour. Paleon.*, Vol. 16, No. 6 (1942), p. 678.

[58] Edwin D. McKee, "A Conularia from the Permian of Arizona," *Jour. Paleon.*, Vol. 9, No. 5 (1935), p. 429.

FIG. 6.—Triassic redbeds of Woodside and Thaynes formations compose hills in foreground. Gros Ventre River cuts through redbeds, separating Red Butte (on right side of river) from other "Red Hills."

TRIASSIC

General description.—The Triassic in the Gros Ventre River area is represented by the Dinwoody, Woodside, and Thaynes formations. They crop out along the Gros Ventre River from Turpin Creek southeastward to Crystal Creek. The belt of outcrop widens considerably in the Crystal Creek region, and the redbeds of the Woodside and Thaynes formations form the colorful "Red Hills" (Fig. 6). Three miles south of the mouth of Crystal Creek the belt of outcrop narrows considerably but continues southward and forms cliffs along the eastern side of Crystal Creek. The Woodside and Thaynes also crop out north of the Gros Ventre River along Ditch Creek.

The Triassic beds are nearly 1200 feet thick. The lower 235 feet, which make up the Dinwoody formation, are mainly tan and gray limestones and siltstones. They are overlain by more than 950 feet of redbeds consisting mainly of shale, sandstone, and siltstone. All three formations are probably Lower Triassic in age.

DINWOODY FORMATION

The Dinwoody formation was originally described by Blackwelder[59] from outcrops of the formation in Dinwoody Canyon on the northeastern slope of the Wind River Mountains, near Du Bois, Wyoming. In the Gros Ventre River area it consists of 235 feet of tan and gray siltstones and limestones between the Phosphoria formation below and the redbeds above.

Newell and Kummel[60] have recognized three major divisions in the Dinwoody:

[59] Eliot Blackwelder, *op. cit.* (1918), p. 425.

[60] Norman D. Newell and Bernhard Kummel, "Lower Eo-Triassic Stratigraphy, Western Wyoming and Southeast Idaho," *Bull. Geol. Soc. America*, Vol. 53 (1942), p. 941.

a "basal siltstone," the "*Lingula*" zone, and an upper division, the "*Claria*" zone. According to Newell and Kummel, the lower "basal siltstone" is not present in the Gros Ventre River area probably because of non-deposition. However, the "*Lingula*" and "*Claria*" zones are present. Since Newell and Kummel have discussed the Dinwoody in some detail and have given a detailed section measured in the Gros Ventre River area, it seems unnecessary to discuss it further in this paper.

WOODSIDE AND THAYNES FORMATIONS

The Woodside and overlying Thaynes are two formations originally named by Boutwell[61] in the Park City mining district of northeastern Utah. Newell and Kummel[62] have extended the use of these names as far east as the Gros Ventre Range.

The Woodside consists of 553 feet of red shale,[63] siltstone and sandstone in the Gros Ventre River area. In the type locality it consists of a little more than 1,000 feet of maroon and red siltstone. Newell and Kummel[64] consider that the western Wyoming redbeds belong to the same facies as the type Woodside, but believe that they correspond stratigraphically only with about the upper half of the Woodside of the Park City area.

In the Gros Ventre River area, the bottom of the first prominent limestone in the redbed series is taken as the Woodside-Thaynes boundary. The beds above are dominantly red shales, sandstones, and siltstones with a few thin limestones. They differ considerably from the type Thaynes, which is essentially calcareous.[65] Newell and Kummel have stated that:[66]

> The lower Thaynes is lithologically well defined and easily recognized as far northeastward as the canyon of the Snake River in the Wyoming Range, near Hoback post office in western Wyoming. Reconnaissance observations indicate profound changes in the Thaynes in the score or so miles between this locality and sections in Hoback Canyon and Gros Ventre Canyon just east of Jackson Hole. Although time did not permit more than cursory examination of the Thaynes equivalents there appears to be a profound convergence or overlap of the Thaynes toward the north and east. . . . Near Hoback post office, on Snake River, the Thaynes includes probably 1,000 feet or more of silty limestones and buff shales, with only minor quantities of red beds. Thaynes equivalents in Hoback Canyon and Gros Ventre Canyon are apparently less than half as thick and consist principally of red beds with relatively inconspicuous purplish to white dolomitic limestones.

Since detailed sections of both the Woodside and Thaynes are given by Newell and Kummel for the Gros Ventre River area, they are not repeated here.

Because the Woodside-Thaynes boundary is very difficult to recognize in the

[61] John M. Boutwell, "Geology and Ore Deposits of the Park City District, Utah," *U. S. Geol. Survey Prof. Paper 77* (1912), pp. 52, 55.

[62] Norman D. Newell and Bernhard Kummel, *op. cit.*

[63] *Ibid.*, p. 969.

[64] *Ibid.*, p. 947.

[65] John M. Boutwell, *op. cit.*, p. 55.

[66] Norman D. Newell and Bernhard Kummel, *op. cit.*, p. 948.

Gros Ventre area, the two formations were considered as one unit in mapping. In fact, in view of this difficulty and the lack of typical Thaynes lithology in the Gros Ventre River area, it might be justifiable to refer all of the redbeds now included in the Woodside and Thaynes to a single formation, the Chugwater. The name Chugwater has been used by Love and others[67] on the east side of the Wind River Mountains to include 1,000–1,250 feet of beds overlying the Dinwoody and underlying the Nugget formation. The term could be applied in the same sense in the Gros Ventre River area. Also, the Alcova limestone, which is a persistent member of the Chugwater in the Wind River area, may be present in the Gros Ventre area.[68]

JURASSIC

General description.—Jurassic rocks crop out in the same general area as that of the Triassic system. They are exposed on Turpin Creek and crop out in a broad band along the Gros Ventre River southeastward to Crystal Creek. Near the mouth of Crystal Creek they swing southward, are exposed in cliffs along Crystal Creek, and make up part of the divide between it and the Gros Ventre River. Jurassic rocks are also exposed on Ditch Creek.

The Jurassic system is represented by the Nugget sandstone, the Twin Creek limestone, the Stump sandstone, and the Morrison (?) formation. The Nugget sandstone, the oldest Jurassic formation is orange to salmon-colored, cross-bedded sandstone. It is overlain by the dominantly gray shales and limestones of the Twin Creek, above which occur the greenish sandstones and shales of the Stump formation. The Morrison formation may also be represented. Since the Morrison (?) beds have not been definitely separated from the overlying Cloverly of the Cretaceous, the question of their occurrence is treated under the Cretaceous.

NUGGET SANDSTONE

The Nugget sandstone characteristically forms orange-colored cliffs in the Gros Ventre River area. It varies in color from pink to buff to orange, but is ordinarily buff or orange. It is generally massively bedded and cross-bedded in places. The sand grains are mostly small and uniform in size. They are somewhat rounded and many of them are frosted. The cement is siliceous, and in some places the sandstone is quartzitic. It is about 150 feet thick in the Gros Ventre River area but thins to the north and is only about 50 feet thick on Ditch Creek. Except for a white sandstone 3–10 feet thick, present in most localities at the base of the formation, the lithologic character varies little vertically. There are no recognizable units within the formation which can be traced laterally. As yet, no fossils have been found in it.

[67] J. D. Love, C. O. Johnson, H. L. Nace, and others, "Stratigraphic Sections and Thickness Maps of Triassic Rocks in Central Wyoming," *U. S. Geol. Survey Prelim. Chart 17*, Oil and Gas Inves. Ser. (1945).

[68] Norman D. Newell and Bernhard Kummel, *op. cit.*, p. 948.

The Nugget formation was originally named by Veatch[69] from outcrops of the sandstone in southwestern Wyoming. It is present over much of western and central Wyoming and in eastern Idaho. Along the Idaho-Wyoming boundary it is at least 1,200 feet thick[70] but it thins eastward and northward. Love and others[71] state:

> The Nugget is the most spectacular sandstone wedge in central Wyoming. It is 500 feet thick at the southwest margin of the Wind River Basin, thins to the north and east, and is absent in most places north of the Owl Creek Mountains and along the eastern margin of the Wind River Basin.

The Nugget sandstone is probably Middle or Lower Jurassic in age. Imlay[72] believes that it may be Lower Jurassic because of the finding of Bajocian (lower Middle Jurassic) ammonites some distance above the base of the Twin Creek limestone. According to Baker, Dane and Reeside,[73] the Nugget is the equivalent of the Navajo sandstone of southern Utah.

TWIN CREEK LIMESTONE

The Twin Creek limestone overlies the Nugget sandstone. It consists mainly of gray limestones, gray to buff shales, with a little red shale and siltstone. The following section was measured about 1½ miles east of Kelly's Slide on the north side of the Gros Ventre River.

Unit	*Thickness (Feet)*
13. Shale and shaly sandstone; gray; soft; mostly covered	46
12. Shale; probably almost entirely greenish gray shale; lower 140–150 feet contains many *Gryphaea calceola* var. *nebrascensis* Meek and Hayden and some other fossils	178
11. Limestone, gray; massive with some fossils; oölitic	5 to 6
10. Covered; probably occupied by gray shale	37
9. Limestone, gray; lower 5 feet very finely crystalline; upper part fossiliferous and with oölites larger than those of interval 4	21
8. Covered; probably greenish gray and red shales	95
7. Shale, dark gray; breaks into angular fragments	15
6. Limestone, bluish gray, weathers buff; argillaceous; contains *Finna, Gervillia, Gryphea planoconvexa, Modiolus subimbricate* White?, *Pleuromya, Comptonectes, Cucullae, Trigonia, Lima, Anatina punctola* (Stanton)	0.7
5. Shale, dark gray; in part calcareous; breaks into angular fragments and contains numerous pelecypods (*Pholadomya, Pleuromya, Astarte, Trigonia*), gastropods, a few cephalopods and brachiopods	9

[69] A. C. Veatch, "Geography and Geology of a Portion of Southwestern Wyoming and Special Reference to Coal and Oil," *U. S. Geol. Survey Prof. Paper 56* (1907), p. 56.

[70] Joseph Neely, "Stratigraphy of the Sundance Formation and Related Jurassic Rocks in Wyoming and Their Petroleum Aspects," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 6 (1937), p. 723.

[71] J. D. Love, Harry A. Tourtelot, Chester O. Johnson, and others, "Stratigraphic Sections and Thickness Maps of Jurassic Rocks in Central Wyoming," *U. S. Geol. Survey Chart 14*, Oil and Gas Inves. Ser. (1945).

[72] Ralph W. Imlay, "Occurrence of Middle Jurassic Rocks in Western Interior of United States," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 29, No. 7 (1945), p. 1022.

[73] A. A. Baker, C. H. Dane, and J. B. Reeside, Jr., "Correlation of the Jurassic Formations of Parts of Utah, Arizona, New Mexico and Colorado," *U. S. Geol. Survey Prof. Paper 183* (1936), p. 3.

Unit	*Thickness (Feet)*
4. Limestone, dark gray; finely crystalline; thin-bedded in lower part and thick-bedded in upper part; contains very minute oölites	16 to 17
3. Covered; probably gray shale in upper part and red shale in lower part	18
2. Limestone, light gray; crystalline; massive; upper part finer crystalline than lower; lower part somewhat arenaceous and containing numerous rounded and angular fragments of limestone	28
1. Shale, grayish green and red; lower part red and arenaceous	5 to 6
Total thickness of Twin Creek limestone	473·7 to 476·7

The Twin Creek has several fossiliferous zones. Neely[74] lists a number of species collected from the Twin Creek in the Gros Ventre area. The collections from the foregoing section have not been studied yet. The outstanding fossil zone, very useful in mapping, is the *Gryphaea* zone near the top of the formation. From a distance it may be recognized as a light buff-colored shale slope, and on the outcrop it is recognized by the thousands of *Gryphaea calceola* var. *nebrascensis* which weather out of it.

The Twin Creek limestone was named by Veatch[75] from exposures of the limestone in southwestern Wyoming. Neely[76] reports a thickness of 2,800 feet for the Twin Creek in the western part of the state, but it becomes thinner on the east. Dobrovolney[77] measured 725 feet near Camp Davis. In the Gros Ventre area it is about 470 feet thick.

Imlay[78] has shown that the Twin Creek formation is probably Middle and lower Upper Jurassic in age in southeastern Idaho. The age relations of the Twin Creek in the Gros Ventre River area to that of southeastern Idaho can not be determined until the fossils are studied, but it seems likely that it is also Middle and lower Upper Jurassic. It is probably equivalent to the Gypsum Spring and part of the "Lower Sundance" of central Wyoming and to the lower Ellis formation of Montana. The first three units of the measured section are considered to be the equivalent of the Gypsum Spring formation, but they do not form an easily mapped unit.

STUMP SANDSTONE

About 250 feet of greenish sandstones and shales are placed in the Stump formation. The Preuss sandstone, which overlies the Twin Creek farther west, was not definitely recognized in this area, but it may be present because the beds at the top of the Twin Creek and base of the Stump are so poorly exposed that the lithologic character could be not clearly seen. The following section of the

[74] Joseph Neely, *op. cit.*, p. 729.

[75] A. C. Veatch, *op. cit.*, p. 56.

[76] Joseph Neely, *op. cit.*, p. 724.

[77] Ernest Dobrovolney, "Jurassic and Cretaceous Strata of the Camp Davis Area, Wyoming," *Papers Michigan Acad. Sci., Arts, and Letters*, Vol. 26 (1940, published in 1941), p. 431.

[78] Ralph W. Imlay, *op. cit.*, p. 1020.

Stump was measured about 1½ miles above Kelly's landslide on the northeast side of the Gros Ventre River.

Unit	*Thickness (Feet)*
14. Shale, black and greenish black, weathers maroon; bedding about 6 inches thick	4
13. Covered	21
12. Sandstone, weathers buff; massive; medium-grained; cross-bedded; poorly cemented	23
11. Covered	36
10. Sandstone, gray; massive; weathers into thin layers	18
9. Covered; probably red and gray sandstone and shale	43.8
8. Sandstone and shale; gray sandstone; massive, weathering into thin layers; same interbedded greenish gray shale	21
7. Covered; probably shaly sandstone and sandy shale	25
6. Sandstone, greenish gray; massive; cross-bedded; weathers into thin layers	60
5. Limestone, yellowish to brownish; arenaceous; contains numerous rhynchonellids (cf. *Kallirhyncia myrina*) and some pelecypods	0.8
4. Shale, green; arenaceous	2
3. Sandstone, greenish gray; massive; weathers into thin layers (flagstones) with even bedding 1–3 inches thick	23
2. Mostly covered; probably shale; may contain glauconite	55
1. Siltstone, red; mostly covered	15
Total thickness of Stump formation	347.6

Note: The green-colored sandstones and shales probably derive their color largely from glauconite.

The Stump beds show considerable variation and inter-fingering laterally. It is difficult to trace horizontally any of the beds, excepting a few massive sandstones. The upper contact of the Stump is gradational, and the beds are not well exposed. The contact was arbitrarily placed below the buff and white sparkly sandstone of a type which occurs in places at several horizons in the Cloverly formation.

The Stump formation was named for Stump Peak in the Freedom Quadrangle, Idaho.[79] It was recognized by Horberg[80] in the Teton area, and although not recognized by Neely is believed to be present in the Gros Ventre River area. It is probably equivalent to what is generally termed upper Sundance in central Wyoming and to the upper part of the Ellis formation of Montana.

It may be that the upper Stump contact should be placed lower, possibly at the top of unit 6 or 8 and that the sandstones and shales above represent the Morrison formation. However, since these beds do not form a mappable unit and are lithologically like the Stump, they were included in the Stump formation. More information is needed to prove or disprove the presence of the Morrison formation.

CRETACEOUS

General description.—The Cretaceous system in the Mount Leidy Highlands is about 9,800 feet thick. Probably about 250 feet of this is Lower Cretaceous,

[79] G. R. Mansfield and P. V. Roundy, "Revision of the Beckwith and Bear River Formations of Southeastern Idaho," *U. S. Geol. Survey Prof. Paper 98-G* (1916), p. 81.

[80] Leland Horberg, *op. cit.*, p. 20.

the remainder, Upper Cretaceous. The Lower Cretaceous sediments are probably continental whereas the Upper Cretaceous includes both continental and marine deposits.

The Lower Cretaceous crops out in a long narrow belt extending from the south-central part of the area north-northwest across the Gros Ventre River. It continues northwesterly and finally is covered by the Tertiary on the northwest side of Turpin Creek.

The Upper Cretaceous covers a broad area west and north of the Gros Ventre River and the area near Spread Creek and Buffalo Fork. It has a larger area of outcrop than any other system.

The Upper Cretaceous of this area represents neither the continental nor the deep basin facies, but is an intermediate type. The marginal facies is north and east of this area, and the region of greatest deposition is on the south. Because of this intermediate paleogeographical location of the Mount Leidy Highlands area with reference to the Cretaceous seas, it is to be expected that both continental and marine sediments would be present.

The Cretaceous beds of the Mount Leidy Highlands are more like those of the Bighorn basin and central Wyoming than those of the deep basin in southwestern Wyoming. Therefore, the terminology of the eastern and southeastern sequences has been applied.

CLOVERLY FORMATION

General description.—Overlying the Jurassic Stump formation is a series of variegated shales with some interbedded sandstone and gray lithographic limestone. The beds, which are extremely variable, generally can not be traced horizontally. They resemble beds of both the Morrison and Cloverly formations of other localities. They are called Cloverly here, mainly because there is some fossil evidence which indicates Cretaceous age. However, part of them may belong to the Morrison formation.

The following section was measured on the north side of the Gros Ventre River, about 2 miles above the Lower Gros Ventre River landslide.

Unit	*Thickness (Feet)*
10. Covered; probably mainly gray shales and clay beds	57
9. Shale, gray at base, red above with dark gray algal-like concretions; dark gray at top	24
8. Limestone, gray with numerous gray limestone pebbles ⅛–1 inch in diameter	½
7. Limestone, slightly darker gray than the underlying limestone; finely crystalline to lithographic; high calcium content; basal part concretionary	9½
6. Limestone, very light gray with earthy feel and conchoidal fracture; argillaceous	9½
5. Shale, red to purple to green; algal (?) concretions present in the green beds along with botryoidal masses of chalcedony, possibly representing replacement of the calcareous algal (?) concretions	81
4. Shale, red; in places gastroliths (?) on surface; mostly covered	29½
3. Sandstone, gray to white; sparkly; coarse-grained; thin-bedded; friable	4
2. Sandstone, yellowish brown; coarse-grained; lower part thicker-bedded than upper; several beds 1–14 inches thick; reddish and better cemented than beds of rest of interval; many chert fragments and much secondary quartz; cross-bedded	16
1. Sandstone, white with pink streaks; some massive and some thin-bedded; sparkly	6
Total	237

Near the Gros Ventre River Red Hills bridge, about 6 miles southeast of the foregoing locality, the Cloverly section is somewhat thicker. It is estimated to be 337–364 feet thick.

In the upper part of the formation a conglomerate is present in places. It is either not persistent or happened to be covered in the foregoing section. Where seen, it is composed mainly of well rounded light and dark gray limestone pebbles with an average diameter of $\frac{3}{8}$ inch. In some places polished quartzite pebbles more than 2 inches in diameter occur. These are like the gastroliths which weather out of the shales below. The greatest thickness observed was 10 feet.

The section of the Cloverly measured above the lower Gros Ventre landslide is considerably thinner than the section on the southeast in the Red Hills. The thickening is largely due to additional beds, mainly variegated shales, at the top of the formation, but because the beds are extremely irregular and variable throughout the formation, definite proof of erosion was not seen.

If there is a disconformity at the top of the variegated shales, it may be the boundary between the Lower and Upper Cretaceous. In any case, there is an outstanding lithologic break here, which is clearly recognizable throughout the area in which the beds are exposed.

Few fossils have been found in this formation. Highly polished quartzite and chert pebbles are common. These are identical with the so-called gastroliths which are reported from both the Morrison and Cloverly formations in other regions. They occur in the shales and also in conglomerates which are near the top of the formation in some localities.

Limestone beds of the Cloverly sequence have yielded a few very poorly preserved pelecypods. Reeside[81] found a few specimens in the gray lithographic limestone above the purple shale (see unit 6 of Cloverly section). He believes that they definitely indicate Cretaceous age.

Correlation.—The variegated beds were originally called Morrison (?) in the Gros Ventre River area because of their stratigraphic position and their lithologic similarity to the Morrison formation of other areas.[82] However, the lithologic appearance is also very much like that of the Cloverly formation of the Wind River and Bighorn basins. Also, the few fossils suggest that the beds, or at least part of them, are Cretaceous rather than Jurassic. There may be an unconformity at the top of the beds, but no evident break occurs within the series, so that it can not be divided into the two formations, the Morrison and the Cloverly. Thus, until it is established that the Morrison formation is represented, the name Cloverly seems most applicable. Love and others[83] in describing probably equivalent beds in central Wyoming did not divide the Morrison and Cloverly but used the two words together in naming the formation. The beds below their quartz crystal

[81] J. B. Reeside, Jr., informal communication (1944).

[82] Joseph Neely, *op. cit.*, p. 729.

[83] J. D. Love and others, "Stratigraphic Sections and Thickness Maps of Lower Cretaceous and Non-Marine Jurassic Rocks of Central Wyoming," *U. S. Geol. Survey Chart 13*, Oil and Gas Inves. Ser. (1945).

sandstone, which they included in the Morrison and Cloverly, may be equivalent to some of the upper sandstone and shale beds here included in the Stump.

On the basis of the invertebrate fossils found by Reeside in the Cloverly formation in the Gros Ventre River area the beds are probably Lower Cretaceous, although the lower part may be equivalent to the Jurassic Morrison. The Cloverly resembles lithologically parts of the Gannett group of the Teton and Hoback mountains. Purple and red siltstones and gray lithographic limestones are common in both formations. Also, limestone pebble conglomerates occur in the Cloverly which are almost identical with some in the Gannett. Most of the Gannett is considered to be Lower Cretaceous.[84] Stokes[85] considers the Ephraim conglomerate, the oldest formation in the Gannett group, as probably equivalent to the Morrison, but has no conclusive fossil evidence. Imlay[86] also considers the Ephraim conglomerate of the Gannett group as equivalent, in part, to the Morrison. Thus, a small part of the lower Gannett group may be correlated with the Morrison whereas the younger and larger part is probably correlated with the Cloverly.

The Cloverly formation was originally named by Darton[87] for Cloverly, a post-office on the east side of the Bighorn Basin in Wyoming. Beds of the Cloverly were described throughout the Bighorn Basin by Lupton,[88] Hewett,[89] and others and the name was applied to similar beds in the Wind River Basin. Moulton and Knappen[90] recognized the Cloverly in southern Montana.

In the Bighorn Basin the top of the Cloverly has been placed above a light-buff or tan-colored sandstone called the Greybull sandstone member. Above this sandstone member commonly occur a group of thin sandstones and shales called the "rusty beds." Hewett and Lupton[91] and later Moulton and Knappen,[92] who considered the Greybull sandstone as the top of the Cloverly formation, placed the overlying "rusty beds" in the Thermopolis shale. Others including Lee[93] and

[84] Raymond E. Peck, "Lower Cretaceous Rocky Mountain Nonmarine Microfossils," *Jour. Paleon.*, Vol. 15, No. 3 (1941), p. 286.

[85] William L. Stokes, "Morrison Formation and Related Deposits in and Adjacent to the Colorado Plateau," *Bull. Geol. Soc. America*, Vol. 55 (1944), p. 969.

[86] Ralph W. Imlay, *op. cit.*, p. 1020.

[87] N. H. Darton, "Comparison of the Stratigraphy of the Black Hills, Bighorn Mountains, and Rocky Mountain Front Range," *Bull. Geol. Soc. America*, Vol. 15 (1904), p. 398.

[88] Charles T. Lupton, "Oil and Gas near Basin, Big Horn County, Wyoming," *U. S. Geol. Survey Bull. 621*, Pt. 2 (1915), p. 168.

[89] D. F. Hewett, "The Shoshone River Section, Wyoming," *U. S. Geol. Survey Bull. 541* (1912), pp. 94–95.

[90] G. F. Moulton and R. S. Knappen, "Geology and Mineral Resources of Parts of Carbon, Big Horn, Yellowstone and Stillwater Counties, Montana," *U. S. Geol. Survey Bull. 822-A* (1930), pp. 23–25.

[91] D. F. Hewett and C. T. Lupton, "Anticlines in the Southern Part of the Bighorn Basin, Wyoming," *U. S. Geol. Survey Bull. 656* (1917), p. 19.

[92] G. F. Moulton and R. S. Knappen, *op. cit.*, p. 26.

[93] Willis T. Lee, "Correlation of Geologic Formations between East Central Colorado, Central Wyoming, and Southern Montana, *U. S. Geol. Survey Prof. Paper 149* (1927).

more recently Love[94] placed the "rusty beds" in the Cloverly. In the Gros Ventre River area the Greybull sandstone has not been definitely recognized, although a thin sandstone is present in some places at the top of the variegated shales. The "rusty beds" may be equivalent to what is here called the Thermopolis shale or to the lower part of it. Thus the Cloverly of the Gros Ventre River region is probably equivalent to Hewett and Lupton's Cloverly, to the Cloverly of Knappen and Moulton, and to the lower two zones of the Morrison and Cloverly of Love and others in central Wyoming. In some places sparkly sandstones occur in the Gros Ventre River Cloverly which resemble the "quartz crystal sandstones" which occur in central Wyoming. Sparkly quartz crystal sandstones are also reported from the Kootenai[95] of south-central Montana, which has also been correlated with the Cloverly.

Figure 8 shows the probable correlation of the Gros Ventre River Cloverly with strata of other areas.

THERMOPOLIS SHALE

General description.—The Thermopolis shale overlies the variegated shales of the Cloverly formation. It consists of a group of interbedded sandstones and shales of prevailingly dark color. Near the top of the formation some beds of dense gray limestone and dolomite occur. Commonly the basal beds of the formation make conspicuous cliffs above the softer and more brightly colored shales of the Cloverly. It is about 318 feet thick.

Detailed description.—The following section of the Thermopolis shale was measured on the west side of Slate Creek just above its mouth (Fig. 5). Here the formation is exposed in two prominent cliffs with covered slopes between.

Unit	*Thickness (Feet)*
13. Tan slope; gypsum crystals	26½
12. Shale, sandstone and limestone; cliff-forming; bottom of cliff consists of dark gray, nodular shale and some thin-bedded shale; shale has nodules of pyrite and lenses of dense gray limestone which weather buff and rusty; top of the cliff is tan shale with slabby tan sandstones, interbedded shales and some beds of dense gray limestone; limestone weathers brown and contains mud cracks; slabby tan sandstone at top is ripple marked; sandstone in places extends down into vertical fractures in cliff	42
11. Covered interval; probably gray shale	36½
10. Shale with two or three ledges of dense gray dolomite; shale is dark gray to black; mostly black; weathers mainly to very fine fragments, $\frac{1}{16}$–$\frac{1}{8}$ inch in diameter; some shale beds which weather into slabs have worm trails; dolomite ledges weather rusty and black and are ½–1 foot thick	71½
9. Shale and sandstone interbedded, dominantly shale; shales are lighter-colored (gray) near base, becoming darker and more splintery near top; some have irregular markings; near base a greenish shale; interbedded sandstones are fine-grained, almost quartzitic; some show fine laminations; unit more shaly near top; forms cliff	52
8. Sandstone and shale interbedded; sandstone whitish, weathers buff to purplish; very irregularly bedded; forms three definite ledges, 2 feet exposed in each ledge; other sandstone beds may be covered; shales, gray to black, form gray slope; vary from splintery material to types breaking into fragments 6 inches long; irregular markings on surface; some is pitted like raindrop impressions, but deeper	37

[94] J. D. Love, *op. cit., U. S. Geol. Survey Prelim. Chart 13.*

[95] L. S. Gardner, T. A. Hendricks, and others, "Mesozoic and Paleozoic Formations in South-Central Montana," *U. S. Geol. Survey Prelim. Chart 18,* Oil and Gas Inves. Ser. (1945).

Unit	*Thickness (Feet)*
7. Sandstone, whitish, weathers buff to purplish; very irregularly bedded; cliff-forming; cliff face is nodular and weathers irregularly	4½
6. Shale, dark gray to black, weathers gray; makes gray shale slope; irregular markings	18½
5. Sandstone and shales; sandstone is white with rust-colored grains throughout; weathers buff with pinkish tinge; massive to thin-bedded; cross-bedded; massive sandstone is cliff-former; some worm trails in sandstone at top of unit; shale, gray, weathers white in places; paper-thin	15½ ±
4. Sandstone, white with rust-colored grains; weathers buff with pinkish tinge; very fine-grained; cross-bedded; massive bedding, 8–20 inches thick; cliff-forming	4
3. Sandstone and shales interbedded; sandstone, white with rust-colored sand grains; weathers buff; very fine-grained; bedding ⅛–4 inches, average 2 inches; shale, gray rusty on weathered surface; thin-bedded	4
2. Shale, dark gray, rusty stain; thin-bedded; unit partly covered (15 inches exposed)	5 ±
1. Sandstone, light buff, weathers buff and light gray; thin irregular beds ⅛–½ inch thick; weathers into slabs; irregular markings on surface resembling worm trails	1
Total thickness	318 ±

Use of name Thermopolis.—The type locality for the Thermopolis shale is near the town of Thermopolis in Hot Springs County, Wyoming. The name was applied by Lupton[96] to a mass of generally shaly rocks limited below by the top of the Greybull sandstone member of the Cloverly formation and above by the base of the Mowry shale. In the Bighorn Basin it contains a persistent sandstone member known as the Muddy sand. Since the Greybull and Muddy sandstones could not be recognized in the Gros Ventre River area, the name Thermopolis has been applied to the group of dark-colored sandstones and shales which occur between the top of the variegated shales of the Cloverly and the base of the salt-and-pepper sandstones, bentonites, and procellanites of the Mowry shale.

Thermopolis-Mowry contact.—The contact between the Thermopolis and Mowry shales, as in most other areas, is gradational. The base of the Mowry was chosen at the bottom of the first salt-and-pepper sandstone, which is a type of sandstone occurring throughout the vertical extent of the Mowry. Above this sandstone, the shales are of the Mowry type and much bentonite is interbedded. Below this sandstone no bentonite was observed. The placing of the contact here was also useful for mapping because in many places it could be recognized from a distance as the third prominent ledge above the Cloverly.

The Muddy sandstone, which is a good marker in other areas, has not been found in the Gros Ventre River area. There is a possibility that it is represented by the basal salt-and-pepper sandstone which is here included in the Mowry formation. The base of the salt-and-pepper sandstone lies about 324 feet above the base of the variegated shales. On Horse Creek on the east side of the Wind River Mountains the base of the Muddy sandstone is about 300 feet above the top of the variegated shales.[97] If the two sandstones are correlative, the 75 feet of shale and bentonite overlying the sandstone would be included in the Thermopolis shale instead of in the Mowry. However, because the correlation of the

[96] Charles T. Lupton, *op. cit.*, p. 168.

[97] John D. Love and others, *op. cit.*, *U. S. Geol. Survey Prelim. Chart 13.*

basal salt-and-pepper sandstone with the Muddy sandstone is problematical, and the sandstone and overlying shales are lithologically more closely related to the Mowry, it seems best for the present, to place the upper Thermopolis contact at the base of the salt-and-pepper sandstone.

Age and correlation.—Since no fossils were found in the Thermopolis shale, its age can not be definitely determined. Its stratigraphic position and lithologic character suggest correlation with the Bear River formation of southwestern Wyoming. The nearest outcrops of the Bear River formation are along the Hoback River 15 or 20 miles from outcrops of the Thermopolis along the Gros Ventre River. The Bear River has a distinctive brackish-water fauna which is considered to be Upper Cretaceous in age.[98] Thus, this correlation suggests Upper Cretaceous age for the beds referred to the Thermopolis in the Gros Ventre area. Also, as previously discussed, there may be a disconformity at the top of the Cloverly, which marks the boundary between the Lower and Upper Cretaceous. The Thermopolis in this area may therefore represent the lowest of the Upper Cretaceous formations. On the other hand, if the basal salt-and-pepper sandstone of the Mowry is equivalent to the Muddy sandstone, according to Reeside's 1944 Upper Cretaceous correlation chart, the Muddy sandstone is at the base of the Upper Cretaceous, and the Thermopolis, then, is both Upper and Lower Cretaceous. The solution of this problem will have to await the finding of fossil evidence. However, on the basis of present knowledge, the writer considers the Thermopolis as Upper Cretaceous. Figure 8 shows a possible correlation of the Thermopolis of the Gros Ventre River area with other parts of Wyoming and southern Montana.

MOWRY SHALE

General description.—The Mowry shale in the Gros Ventre River and Mount Leidy Highlands area consists of salt-and-pepper sandstones, black and gray shale, bentonite, thin dolomites, and many porcellanite beds. From a distance it has an over-all gray appearance with distinct light and dark bands (Figure 7). The only fossils discovered were a few fish scales. It is about 1,070 feet thick.

Detailed description.—The following section of the Mowry, with the exception of the two lower units, was measured on the northeast side of the Gros Ventre River below Upper Slide Lake. The lower two units which are not fully exposed here were measured on the west side of Slate Creek a short distance above the mouth.

Unit	*Thickness (Feet)*
41. Covered interval; tan slope; includes black shale beds and yellow bentonite	41
40. Sandstone, tan, lower part weathers brown, upper part weathers gray; friable and massive; some interbedded shale	114
39. Sandstone, brown, weathers tan to brown; salt-and-pepper type; mostly massive and friable	20½

[98] C. A. White, "The Bear River Formation and Its Characteristic Fauna," *U. S. Geol. Survey Bull. 128* (1895), p. 24.

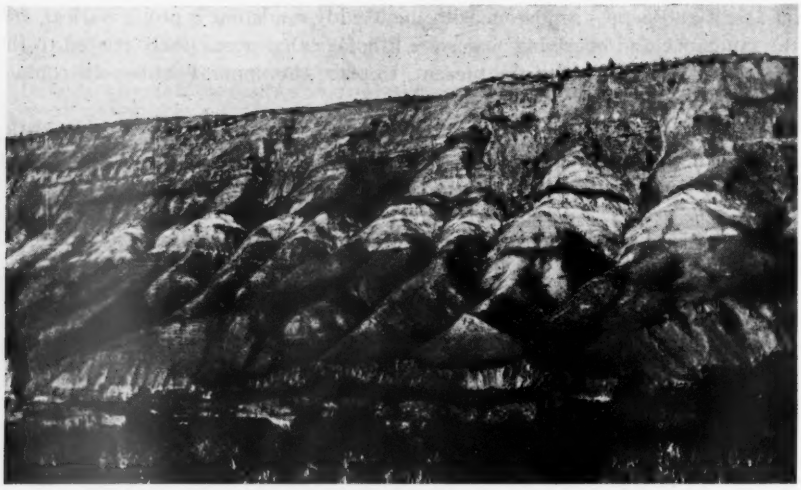


FIG. 7.—Banded Mowry beds overlain by ledges of Frontier sandstone exposed along Gros Ventre River.

Unit	*Thickness (Feet)*
38. Porcellanite or siliceous tuff and shale; porcellanite, white; occurs at base of unit; 6 or 8 inches thick; tan slope above, probably shale	22
37. Sandstone and shale interbedded; sandstones weather buff and in places maroon; blocky, forming ledges; bedding averages 8 inches thick	44
36. Porcellanite or very hard siliceous tuff; dominantly very white and some pink; some weathers rusty brown; bedding ¼–6 inches thick; seems to be persistent and traceable bed; chalky appearance on weathered surface; veinlets of red and white SiO_2	12½
35. Covered gray and tan slope; probably shales and bentonitic shales; black nodules in shales	30
34. Sandstone and shale interbedded; at bottom of unit are shales and yellow bentonitic clays overlain by smooth gray, weathered porcellanite bed 5 inches thick; above is gray, quartzitic sandstone weathering pink overlain by quartzitic sandstones, fine- to coarse-grained, separated by black and tan shale beds; sandstone beds vary from 3 to 12 inches thick	22
33. Sandstone and shales interbedded; ledges of salt-and-pepper and quartzitic sandstone interbedded with tan and black shales; some massive sandstone ledges weather reddish	65
32. Shale and sandstone; lower part is tan slope; above is black shale with white clay bed which separates it into two parts; above is 2½ feet of white tuffaceous material with orange streaks; above is gray quartzitic sandstone about 5 inches thick	10
31. Sandstone and shale; sandstone weathers tan and reddish; very thin to massive bedding (¼–24 inches); shales, dark gray to black, thin-bedded	26
30. Sandstone, salt-and-pepper weathers tan and red; massive	5
29. Shale, gray; nodular in lower part; some thin sandy partings, commonly tan; shale in upper part weathers tan; gypsum veinlets in lower part	19
28. Sandstone, salt-and-pepper, weathers tan; some friable; middle has massive bedding with thin bedding above and below; cavernous; one 6-inch shale bed at top of massive sandstone, black	18
27. Sandstone, gray, weathers light gray; dense and quartzitic; fine-grained; bedding ⅛–3 inches; a little interbedded shale	11
26. Shale, lower part covered; upper part, black shale; bedding ½–1 inch; some splintery	11½
25. Porcellanite, shale and sandstone interbedded; porcellanite, gray and gray and white	

Unit	Thickness (Feet)
banded; in beds 4–12 inches thick with shales between; shales, black and perhaps brown and tan; quartzitic sandstone; porcellanite and gray quartzitic sandstone weather rusty and make beds which appear blocky from distance	31
24. Shale, black, forming gray slope; splintery and thin-bedded	7½
23. Sandstone, salt-and-pepper; well cemented at bottom, becoming more friable at top, weathers brown; can be followed considerable distance as first definite sandstone ledge; massive bedding; first massively bedded sandstone	15½
22. Sandstone, light tan, weathers whitish in places; some interbedded black and brown shales and layers of gray fine-grained quartzitic sandstone; gets more shaly at top; main sandstone is light tan; very thin-bedded; in places paper-thin; weathers to tan slope in most places, but in places stands as cliff	104
21. Covered interval; tan slope; largely black and brown shale with some interbedded sandstone; about half way up gray, fine-grained quartzitic sandstone	41½
20. Shale, black and brown, splintery; makes gray slope; about third way from bottom of unit thin (¼–2 inches) sandstone beds interbedded with shale for about 4 feet; may be more interbedded sandstone; at least two and possibly more bentonite beds; yellow, but weather white	106
19. Bentonitic clay, shale, porcellanite; bentonite bed at base about 2 feet thick overlain by black splintery shale with bed of banded and speckled porcellanite at top (2 feet)	16½
18. Shale, black, weathers to gray slope; breaks into small splintery fragments; thin-bedded; some thin layers of sandstone interbedded	30
17. Shale and sandstone interbedded; ledges of gray quartzitic sandstone 1–4 inches thick interbedded with thin layers of shale	10½
16. Shale, black, thin-bedded; interbedded with thin sandstone layers; alternating beds ⅛–½ inch thick	5
15. Sandstone, gray, quartzitic, fine-grained; laminated appearance; thin-bedded	15
14. Porcellanite; plain gray	⅓
13. Sandstone, gray, quartzitic; almost like porcellanite in places; thin-bedded (⅛–2 inches)	3
12. Shale, partly covered; black shale, rust-stained, weathers to gray slope; some thin clay partings and bentonitic clay interbedded; possibly a little sandstone	50
11. Porcellanite, gray, lower part speckled; upper part plain gray	6
10. Shale, black weathers rusty brown; dense; near top of unit is ledge of gray quartzitic sandstone; bed of yellow bentonitic clay above sandstone and shale	5
9. Porcellanite; at bottom of this interval is dense black shale weathering rusty color; porcellanite has white matrix with gray oval speckles; bedding ½–6 inches; weathers white on surface	5
8. Sandstone, gray salt-and-pepper, type; some quartzitic near top; a little interbedded shale which weathers whitish	10
7. Shale, black weathers to gray slope; contains gray bentonitic clay and has some yellow clayey material; some rust stain; 8 feet above is dense, very dark gray shale; weathers maroon; in places nodular; above is gray porcellanite bed; 6 inches exposed; above is more dense black shale, weathers maroon; thin-bedded gray sandstone occurs about 7 feet below top and is about 1½ feet thick	22
6. Sandstone, gray salt-and-pepper; weathers into white flagstones; bedding variable as in unit 4	17
5. Shale, black and calcareous; 4 inches thick; weathers rusty; fish scales present; porcellanite-like material with fish scales; 4 inches; salt-and-pepper sandstone; one 2-inch layer of brown-gray loose sand overlying salt-and-pepper sandstone; then 10 inches gray quartzitic sandstone	2
4. Sandstone, gray salt-and-pepper; weathers white, making distinct white bed recognizable from distance; laminated; some weathers to flagstone; bedding 1½–14 inches	4
3. Porcellanite, dark and light gray banded; bedding 1/16–6 inches; some irregular markings	4
2. Shale, bentonite, dolomite and sandstone; essentially shale unit; one 1-inch thick, dark gray dense dolomite bed interbedded in shales; shales weather rusty in places and into small splintery fragments; beds which appear white at distance are very light green bentonite; beds up to 10 inches thick; fine-grained gray sandstone, probably dolomitic (might be sandy dolomite) is interbedded in shales; occurs 20–30 feet from top of unit	75±
1. Sandstone, salt-and-pepper	10±
Total	1,067½±

Bentonite and bentonitic clays and shales make up about 25 per cent of the Mowry shale. The beds are commonly light green or yellow on the fresh surface. Slumping is common in these beds.

The Mowry formation is well known for its siliceous shales. In the Gros Ventre River area, not only siliceous shales occur, but also porcellanite beds like those in the Aspen formation in the Teton and Hoback ranges. The porcellanites are very fine-grained, hard, bedded rocks which break with conchoidal fracture. They occur in several colors; some are plain gray, light gray-green, or white and others are white or gray with light green specks or are banded. Some have a pinkish tinge. They occur as separate beds between shales or sandstones, or they grade into siliceous shale or quartzitic sandstone. Megascopically they resemble porcelain. Dobrovolney[99] reports that microscopically they consist mainly of unweathered dust fragments of volcanic glass.

The siliceous shales are commonly dark gray on the fresh surface but weather to an exceptionally silvery gray color. They are very hard and platy and have a subconchoidal fracture. Their exceptional hardness is due to large amounts of silica.[100]

The origin of the siliceous shales of the Mowry was studied by Rubey.[101] He concluded that they are in some way derived from the alteration of volcanic ash. He suggests that the original ash may have been exceptionally siliceous, that it was decomposed by long exposure to sea water, and that the silica dissolved from it was precipitated by decaying organic matter.

The relations of bentonite, porcellanite, and siliceous shales have not been satisfactorily explained. It has been suggested that volcanic ash falling in sea water may have altered to bentonite while that falling in fresh water may have altered to porcellanite. Rubey[102] says that "the composition of the Mowry shale and the associated bentonite is remarkably similar in the high percentage of silica, and the relative proportions of the other constituents, strongly indicating that both contained the same original material." Although many problems remain in connection with the origin of this exceptional deposit, there is little doubt that its origin is connected with volcanic ash.

Many of the sandstones of the Mowry formation are typically light gray with black specks and thus have been called salt-and-pepper sandstones. They occur throughout the vertical extent of the Mowry. Some which are resistant form prominent ledges. The Mowry gradually becomes more sandy nearer the top, and the salt-and-pepper sandstones grade into the tan, friable sandstone which characterizes the Frontier formation.

[99] Ernest Dobrovolney, *op. cit.*, p. 438.

[100] W. W. Rubey, "Origin of the Siliceous Mowry Shale of the Black Hills Region," *U. S. Geol. Survey Prof. Paper 154-D* (1929), p. 154.

[101] *Ibid.*, p. 1.

[102] *Ibid.*, p. 60.

Distribution and correlation.—The Mowry shale has been found in Wyoming, Montana, western South Dakota, and northern Colorado. Throughout most of Wyoming it has a thickness of 100–300 feet, which increases southwestward.[103] In western and southwestern Wyoming the Aspen shale, which is probably the equivalent of the Mowry, is locally more than 2,000 feet thick.

The Mowry in the Gros Ventre River area is transitional between the Mowry of eastern Wyoming and the Aspen shale of southwestern Wyoming. It shows considerable thickening, has the porcellanite of the Aspen farther west, but contains much bentonite and the siliceous shales which characterize the Mowry on the east.

FRONTIER FORMATION

General description.—The Frontier formation in this area is characterized by massive tan-colored sandstones and numerous ledges of resistant sandstone interbedded with tan shales. Friable argillaceous gray and tan sandstones alternate with tan shales to form long buff-colored slopes. In the lower part of the formation are several glauconitic sandstones. There are a few black shales containing poorly preserved plant material but no coal beds were observed. Some of the sandstones contain fossil marine pelecypods, gastropods, and shark teeth. The total thickness of the formation is about 2,750 feet.

Mowry-Frontier contact.—The contact between the Mowry shale and Frontier formation is gradational. As previously noted, the Mowry in this area is characterized by black and gray shales, gray salt-and-pepper sandstones, bentonite, and porcellanite beds. About 740 feet above the base of the Mowry the gray resistant sandstones become less common, and the tan, more friable Frontier type of sandstone appears. Porcellanite and bentonite beds become less common and finally are no longer present. In place of the gray and black shales of the Mowry the tan shale of Frontier type is found.

For mapping purposes, the contact between the Mowry and Frontier formations was placed at the base of a typical Frontier type sandstone, above which no bentonite or porcellanite beds were observed. The shales above are the tan-colored Frontier type whereas those below are largely black and gray. The contact might have been placed 176 feet lower, at the base of the first prominent Frontier type sandstone, but above this sandstone are numerous beds of bentonite and Mowry type shales. Also, the sandstone chosen as the base of the Frontier seemed to be more persistent and more easily recognized for mapping purposes than the lower sandstone.

Detailed description.—The following section of the Frontier formation was measured on the north side of Upper Slide Lake along the Gros Ventre River (Fig. 5).

[103] *Ibid.*, p. 1.

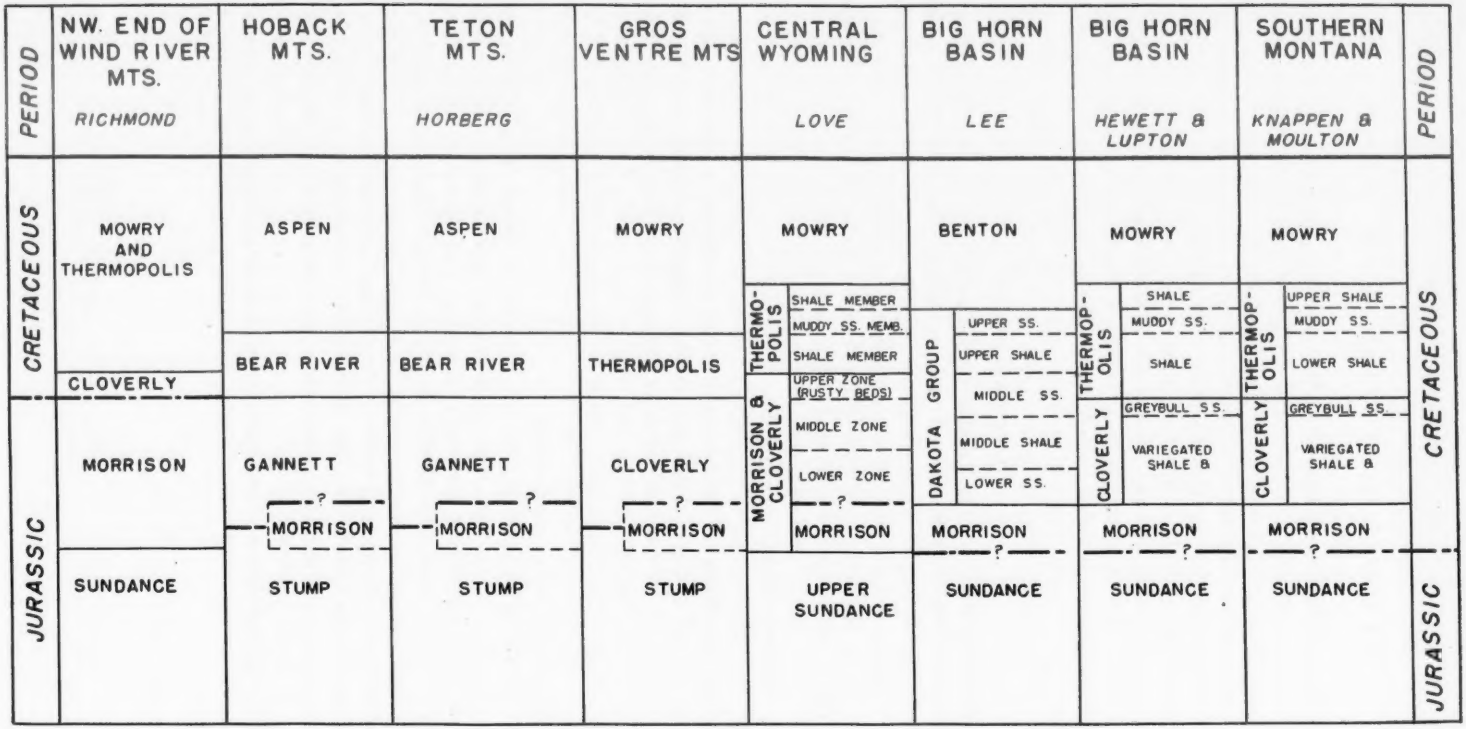


FIG. 8.—Correlation chart for Lower Cretaceous and part of Upper Cretaceous.

Unit	*Thickness (Feet)*
27. Sandstone and covered; lower half covered tan slope, probably friable sandstone and shale; then ledge of more resistant sandstone crops out; gray, weathers somewhat maroon; covered interval, then ledge of massive sandstone; above gray, friable sandstone interbedded with more resistant blocky, brown and maroon weathering sandstone ledges; no fossils noted	153
26. Sandstone and oyster coquina; lower bed is an oyster coquina about 4 feet thick; above is barren, cross-bedded, tan friable sandstone, weathers cavernously and forms prominent ledge on hillside; 5–6 feet exposed; above is another oyster coquina about 2 feet thick overlain by cross-bedded tan friable sandstone about 1 foot thick; then another coquina about 1–1½ feet thick overlain by more cavernous, cross-bedded sandstone; above are two 3-inch layers of oysters on top of cavernous tan sandstone; contains *Ostrea soleniscus* Meek ? var. (young form), *Ostrea* sp. A, *Mesostoma* cf. *M. occidentalis* Stanton, unidentified gastropod and unidentified pelecypod	36½
25. Sandstone and covered; sandstone, gray-brown, weathers brown, friable and argillaceous; crops out at base; about 2 feet exposed; thin-bedded; averaging ¼ inch; slope above covered, probably shale and sandstone	68½
24. Covered interval; tan slope; probably shale with some friable sandstone	261½
23. Sandstone and shales; sandstone, gray, weathers brown and gray; thin-bedded (average ¼ inch); weathers into slabs; interbedded shales are gray; top of unit is gray, fine-grained sandstone, weathers orange-brown and breaks into big slabs; prominent ledge near top of hill	18
22. Covered interval; lower part covered; probably gray shale with some interbedded sandstone; upper part gray shale, making gray slope; upper 300 feet of shale exposed	750
21. Sandstone and shales, partly covered; shales at base; sandy shales becoming more sandy at top and with some sandstone ledges cropping out at top; some of sandstones contain *Inoceramus* and other shells; some thin-bedded and some more massively bedded; sandstone at top cavernous; salt-and-pepper sandstones make tan slope	870
20. Sandstone, brown, weathers reddish in places; friable, thin to massive bedded, thin-bedded at top; cross-bedded; cliff-former	25
19. Sandstone, brown, friable with two ledges of gray, hard sandstone interbedded; gray sandstone, weathers red	21½
18. Sandstone, brown, weathers tan; very friable; cross-bedded; massive to thin-bedded; coarse-grained	32½
17. Shale and conglomerate; shale, black; overlain by conglomerate consisting of pebbles ⅛–1½ inches in diameter; matrix coarse salt-and-pepper sandstone; pebbles largely gray chert with some pink quartzite and a little white, severely weathered limestone; grades above into coarse sandstone; shark teeth sparsely present. (There may be another conglomerate below the shale, but poorly exposed)	1
16. Covered, probably sandstone and some shale; 2 feet oyster coquina in about middle of of unit; contains *Ostrea* sp. D, *Lima?* sp. B. and *Cardium* sp. aff. *C. – – ?* Meek	39
15. Sandstone, gray and tan, weathers with a maroon cast; irregularly thin-bedded and cross-bedded; contains *Inoceramus?* which are 7 inches long and 5½ inches wide	4½
14. Sandstone and shale; covered interval probably consisting of thin-bedded sandstone and perhaps some shale; thin-bedded sandstone above containing *Inoceramus?* fragments; probably some black shale in covered interval above; one ledge of massive tan cross-bedded sandstone overlain by thin-bedded tan and gray sandstone	71
13. Sandstone; at base a thin bed of coarse sandstone with a few fossils; above is 3-inch ledge of gray, quartzitic sandstone; a massive tan sandstone full of *Inoceramus* fragments stands out as ledge; above are thin-bedded sandstones	17½
12. Sandstone ledges; tan to gray; mainly thin-bedded, but some bedding 6–8 inches thick; cliff-former; no fossils observed	22
11. Sandstone and shale; sandstone at base contains *Inoceramus?* fragments, *Pteria gastrodes* Meek, *Pteria* aff. *P. linguiformis* Evans and Shumard, *Pecten* sp., *Pholadomya* aff. *P. coloradoensis* Stanton, *Cardium pauperculum* Meek, *Tellina* sp., *Gyrodes* cf. *G. depressa* Meek, and unidentified pelecypods; non-fossiliferous gray sandstone above; thin-bedded; top of unit is maroon shale; breaks into small splintery fragments	4
10. Sandstone, gray to tan, weathers tan; massive to thin-bedded; cliff-former; may contain some interbedded shale; at base of cliff are *Inoceramus* cf. *I. aculeplicatus* Stanton and *Cardium* sp., aff. *C. – – ?* Meek; a few *Inoceramus* fragments scattered throughout unit	47½
9. Sandstone and shale; sandstone at base, tan, thin-bedded, contains plant fragments; above is light gray, thin-bedded sandstone overlain by black shale; above shale is thin-bedded salt-and-pepper sandstone; partly covered; may be more shales	60½

Unit	*Thickness (Feet)*
8. Sandstone and shale; sandstone light gray, weathers into tan flagstones; bedding $\frac{1}{8}$–$\frac{1}{2}$ inch; two beds of bluish maroon chunky shale, one 7 feet above bottom of unit, other 14½ feet above bottom; may be other interbedded shales	32½
7. Partly covered; just below center of unit is maroon shale, weathers with bluish and maroon cast; chunky	32
6. Shale and sandstone, partly covered; black shale near bottom containing many poorly preserved plant fragments; another black shale near top; at top a green sandstone ledge about 5 inches thick, probably containing glauconite; chunky	17
5. Sandstone, brown, weathers brown and reddish; bottom is thin-bedded becoming massive (4–6 feet); at top is tan and thin-bedded ($\frac{1}{4}$ inch); ripple-marked near bottom; cross-bedded; rust and orange weathering clay nodules near base; rectangular jointing in some places; forms cliff at top of hill which appears reddish from distance	41
4. Sandstone, greenish gray, weathers with light greenish cast; thin-bedded at top and bottom with some massive beds; probably contains glauconite grains; friable; 2-inch black shale at top of unit	22½
3. Sandstone, limestone and shale; thin-bedded gray sandstones with three nodular gray limestones interbedded; limestone beds 8–10 inches thick and somewhat brecciated; at top of unit is fossil bed 8–10 inches thick; weathers rusty brown and is underlain by black shale; *Exogyra* cf. *E. columbella* Meek?, *Lucina* sp., *Cardium pauperculum* Meek, *Mactra formosa* Meek and Hayden?, *Gyrodes depressa* Meek? *Pyropsis?* sp., *Volutoderma?* sp., unidentified pelecypods and shark teeth	51
2. Limestone, gray, weathers rusty brown, nodular	1
1. Sandstone and shale; sandstone tan, friable; lower beds thin-bedded about ¼ inch thick; massive beds above up to 4 feet thick; about 15 or 20 feet above bottom of unit is reddish slope formed by black-brown shale; top is thin-bedded friable tan sandstone; may be other shales interbedded	52½
Total thickness	2,753

Hayden,[104] one of the early workers in southwestern Wyoming, named a prominent topographic feature composed of fossiliferous sandstones Oyster Ridge. Veatch[105] studied these oyster-bearing sandstones and named them the Oyster Ridge sandstone member of the Frontier formation. It was described as a group of sandstones, in places conglomeratic, with numerous specimens of *Ostrea soleniscus* and other species. In the type locality, this member is about 200 feet thick and the base is 600 feet below the top of the Frontier formation.

Units 10 through 17 of the Gros Ventre River section have many of the characteristics of the Oyster Ridge sandstone member and may be its equivalent. This group of beds is 206 feet thick. The sandstones include both massive and thin-bedded types. The massive sandstones are cliff formers. The uppermost unit (17) is conglomeratic. It consists largely of gray chert pebbles, $\frac{1}{8}$ to 1½ inches in diameter. The matrix is a coarse salt-and-pepper sandstone. Units 10 to 17 are the most fossiliferous of the Frontier formation. They contain the following species: *Inoceramus* cf. *I. acuteplicatus* Stanton, *Pteria gastrodes* Meek, *Pteria* aff. *P. linguiformis* Evans and Shumard, *Ostrea soleniscus* Meek, *Ostrea* sp. B. *Ostrea* sp. C. *Ostrea* sp. D., *Ostrea* sp. F, *Ostrea* sp. G., *Pecten* sp., *Lima ?* sp. B, *Phola-*

[104] F. V. Hayden, *Fifth Annual Report of U. S. Geol. and Geog. Survey of the Territories* (1872), p. 149.

[105] A. C. Veatch, "Geography and Geology of a Portion of Southwestern Wyoming and Special Reference to Coal and Oil," *U. S. Geol. Survey Prof. Paper 56* (1907), p. 65.

domya aff. *P. coloradoensis* Stanton, *Cardium pauperculum* Meek, *Cardium* sp. aff. *C.– –?* Meek, *Tellina* sp., *Mactra* sp., *Gyrodes* cf. *G. depressa* Meek.

This fossiliferous group of Frontier beds can be recognized throughout the area described wherever the Frontier is exposed. It forms the top of the ridge on the east side of Goosewing Creek; it also forms a ridge along the north side of Turpin Creek and is seen along the west side of Haystack Fork.

In summary, this group of sandstone beds (units 10 through 17) is probably the equivalent of the Oyster Ridge sandstone member of Veatch. It has corresponding lithologic character and thickness; in each place it is an outstanding fossiliferous horizon; and in both localities it lies considerably below the upper Frontier contact.

Unit 26 is an outstanding fossiliferous zone containing five layers of oyster coquina interbedded with sandstone. A detailed section of the unit follows.

	Feet
Sandstone, tan, containing two 3-inch layers of oysters	15
Sandstone, cavernous, cross-bedded	5
Oyster coquina	1–1½
Sandstone, tan, friable, cross-bedded	1
Oyster coquina	2
Sandstone, tan, friable, cross-bedded, forms prominent ledges on hillside, barren of fossils	2
Oyster coquina	4
Total thickness	30

This unit is commonly a cliff-maker. *Ostrea soleniscus* Meek var. (young form), *Mesostoma* cf. *M. occidentalis* Meek and *Ostrea* sp. A. were collected from unit 26. Other fossils also probably from this zone are: *Pteria gastrodes* Meek, *Ostrea* sp. H, *Veniella* sp., *Cyrena* sp., *Cardium pauperculum* Meek, *Mactra ? arenaria* Meek, *Turritella* sp. B, cf. T. *whitei* Stanton and *Gyrodes* sp.

Fossils of Frontier formation.—In general, the Frontier formation in this area seems to have three fossil zones, the lowest of which occurs about 104 feet above the base of the formation. The fossil bed which is only about 8–10 inches thick, contains the following species.

Exogyra cf. *E. columbella* Meek?
Liopistha meeki White
Cardium pauperculum Meek
Mactra formosa Meek and Hayden
Turritella sp. B. cf. *Turritella whitei* Stanton
Gyrodes depressa Meek?
Pyropsis? sp.
Volutoderma? sp.
Unidentified pelecypods
Shark teeth

This zone is known to occur from Upper Slide Lake along the north side of the Gros Ventre River to Cole Hollow. Although it was not traced farther, it is probably present throughout the region where the lower part of the Frontier is exposed.

The second zone is that of the Oyster Ridge sandstone member. Here the fossils are found throughout a vertical interval of about 206 feet. The following species have been identified.

Inoceramus cf. *I. aculeplicatus* Stanton
Pteria gastrodes Meek
Pteria aff. *P. linguiformis* Evans and Shumard
Ostrea soleniscus Meek
Ostrea sp. B.
Ostrea sp. C
Ostrea sp. D
Ostrea sp. F
Ostrea sp. G
Pecten sp.
Lima? sp. B
Pholadomya aff. *P. coloradoensis* Stanton
Pholadomya cf. *P. coloradoensis* Stanton
Cardium curtum Meek and Hayden
Cardium sp. aff. *C. – – ?* Meek
Cardium pauperculum Meek
Tellina sp.
Mactra sp.
Gyrodes cf. *G. depressa* Meek
Shark teeth

This zone was found in the Cole Hollow vicinity, on the north side of Haystack Fork, on the north side of Turpin Creek, and on the east side of Goosewing Creek. Since the zone is widely exposed throughout the Gros Ventre area it is a good marker.

The uppermost fossil zone occurs about 153 feet below the top of the Frontier formation. It contains several oyster coquinas which include the following species.

Pteria gastrodes Meek
Ostrea soleniscus Meek? var. (young form)
Ostrea sp. A
Ostrea sp. H
Veniella sp.
Cyrena sp.
Cardium pauperculum Meek
Mactra? arenaria
Turritella sp. B. cf. T. *whitei*
Gyrodes sp.

This zone is present in the vicinity of Cole Hollow, but has not been traced to neighboring localities.

The fauna of the Frontier formation in the Gros Ventre River area is most closely related to the fauna of the Colorado formation as described by Stanton.[106] At least eleven of the identified species and all of the genera in the Gros Ventre area were described by Stanton from the Colorado formation. The fauna includes species such as *Exogyra columbella, Cardium pauperculum* and *Turritella whitei,* which, according to Stanton[107] are not known to range into strata above the Colorado formation and are sufficiently abundant and widespread to be used

[106] Timothy W. Stanton, "The Colorado Formation and Its Invertebrate Fauna," *U. S. Geol. Survey Bull. 106* (1893).

[107] *Ibid.*, p. 48.

in correlation. Johnson[108] in his faunal list of the Benton, includes nine species found in the Gros Ventre River area. The Benton group is equivalent to the lower part of the Colorado group.

Reeside[109] believes that the Frontier formation in the Bighorn Basin includes younger rocks than are present at the type locality of the Frontier in Linclon County, Wyoming. He believes that the upper part of the Frontier is Niobrara in age. This may be true for the Gros Ventre area also, as an *Inoceramus* compared with *Inoceramus acuteplicatus*, which is listed by Hansen[110] as a Niobrara fossil, was found in the Frontier there. A *Turritella* compared with *Turritella whitei*, which ranges from the Greenhorn through the Niobrara in age,[111] is also present in the Frontier of the Gros Ventre area.

Appropriateness of name Frontier.—The name Frontier formation was given by Knight[112] to a coal-bearing sandstone formation about 2,000 feet thick which is well developed near the town of Frontier in southwestern Wyoming. Later Veatch[113] studied the formation and gives the thickness of the Frontier as 2,200–2,600 feet. Schultz[114] who examined the Frontier formation and its Oyster Ridge sandstone member in Lincoln County, Wyoming, gives its thickness as 2,400–3,800 feet. Lupton[115] says in his paper on "Oil and Gas near Basin, Bighorn, Wyoming,"

> in the mapping of several coal and oil fields in the state (Wyoming) it has been found that there is generally a group of sandstone and shale beds in the middle of the Colorado shale which is the representative of the Frontier formation of Lincoln County. The individual beds, as well as the group of beds, thin eastward and disappear at about the meridian of Douglas (Wyoming). These beds of sandstone which contain the most prolific oil-bearing sands of the state, have previously been treated as individual members of the Colorado shale, but now it is proposed to consider them collectively as the Frontier formation and to name individual beds as members of this formation.

Thus, the name Frontier has continued to be used in the Bighorn Basin.

The name Frontier has also been applied in the Wind River Basin to a similar group of beds. Collier[116] describes the Frontier formation in Fremont County and

[108] J. Harlan Johnson, "The Benton Fauna of Eastern Colorado and Kansas and Its Recorded Geologic Range," *Jour. Paleon.*, Vol. 4, No. 2 (1930).

[109] Horace D. Thomas, "Frontier-Niobrara Contact in Laramie Basin, Wyoming," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, No. 9 (1936), p. 1194.

[110] G. H. Hansen, "Vertical Range of the More Common Species of the Upper Cretaceous in the Western Interior," *Jour. Paleon.*, Vol. 3, No. 1 (1929), p. 86.

[111] J. Harlan Johnson, *op. cit.*

[112] W. C. Knight, "Coal Fields of Southern Uinta County, Wyoming," *Bull. Geol. Soc. America*, Vol. 13 (1903), p. 542.

[113] A. C. Veatch, *op. cit.*, p. 65.

[114] Alfred R. Schultz, "Geology and Geography of a Portion of Lincoln County, Wyoming," *U. S. Geol. Survey Bull. 543* (1914), p. 61.

[115] Charles T. Lupton, *op. cit.*, pp. 170–71.

[116] A. U. Collier, "Anticlines near Maverick Springs, Fremont County, Wyoming," *U. S. Geol. Survey Bull. 711* (1919), p. 159.

lists a marine fauna from it. Reeside[117] and others have applied the term to Cretaceous strata as far north as southern Montana. Richmond,[118] who mapped the Frontier formation in the northwest Wind River Mountains in Sublette County, Wyoming, states that "to the west the Frontier maintains its character across the Gros Ventre Range."

Thus, on the basis of lithologic similarity, of geographic distribution in relation to neighboring areas where Frontier strata have been described, and of faunal similarity, it seems justifiable to call this group of sandstone beds in the Mount Leidy Quadrangle, the Frontier formation.

Suggested correlation of the Frontier formation of the Gros Ventre River area with that of other regions is shown in Figure 9. Bartram[119] also considers the Blackleaf and Mosley formations of Montana, the Codell of eastern Colorado, and the Ferron sandstone of Utah as Frontier equivalents.

CODY SHALE

General description.—The Frontier formation is overlain conformably by the Cody shale. The Frontier sandstones have been described as tan sandstones of which the more massive beds form ledges and cliffs and some of the more thinly bedded layers weather to flagstones. In contrast, the sandstones of the Cody are typically gray, nodular, and irregular. The shales of the Frontier are tan while those of the Cody are gray and black and commonly of the bony type, which weathers white. Numerous thin lignite beds are present throughout the vertical extent of the Cody. However, there is a zone of gradation between the Frontier and the Cody, and furthermore the contact between the two formations is transitional. There is some intermingling of the two types of sandstones and shales. The contact was arbitrarily chosen at the top of the highest Frontier type sandstone. Below it there are no lignite beds, but immediately above it a lignite series begins and the Cody type shales and sandstones predominate.

Because of the soft, easily weathered nature of the Cody shale, its characteristic topographic expression is a belt of low hills, bordered by the more resistant ledge- and cliff-forming Frontier sandstones below and the massive cliff-forming Mesaverde sandstone above.

The lower part of the Cody is a series of alternating gray sandstones, banded shales, gray clays, and thin lignite beds. This alternation accounts for the banded appearance as seen from a distance. Some of the shales weather whitish, resulting in the conspicuous light-colored bands.

About 475 feet above the base thin beds of nodular gray lithographic lime-

[117] J. B. Reeside, Jr., "A New Fauna from the Colorado Group of Southern Montana," *U. S. Geol. Survey Prof. Paper 132* (1923).

[118] Gerald M. Richmond, "Geology of Northwest End of the Wind River Mountains, Sublette County, Wyoming," *U. S. Geol. Survey Prelim. Map 31*, Oil and Gas Invest. Ser. (1945).

[119] John G. Bartram, "Upper Cretaceous of the Rocky Mountain Area," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 7 (1937), p. 906.

stone first appear. Higher in the section, they occur more commonly. They weather to a characteristic rusty color. It is impossible to trace most of the beds of the Cody more than a few hundred feet horizontally because they are covered. The total thickness of the Cody shale is 1,365 feet in this area.

Detailed description.—The following section of the Cody was measured at Cole Hollow (Fig. 5) on the north side of the Gros Ventre River in the Mount Leidy Quadrangle, Teton County, Wyoming.

Unit	*Thickness (Feet)*
34. Sandstone, shale and limestone interbedded; not traceable as various beds become covered in short distances; several limestone beds, gray, weather rust to tan	65
33. Sandstone, shale, and limestone; eight sandstone ledges; tan, weathering tan to reddish and rust color; shales and lignite interbedded; at least four ledges of dark gray lithographic limestone, weathers rusty; commonly occur just below sandstone ledges; limestone at top of ridge; ripple marks in sandstone	268
32. Limestone, gray, weathers rusty; lithographic	2
31. Covered; probably shale	16
30. Sandstone, brown weathers tan; massive, but more thin-bedded at top; weathers cavernously	9
29. Sandstone and shale; at base is sandstone, brown with white stain on surface; friable; forms ledge 3 feet high; covered interval above; probably shale overlain by sandstone ledge; brown, weathers reddish with white stain; shale above is covered, overlain by sandstone; weathers white and red-brown; thin-bedded; above are alternating shales and tan sandstone	79½
28. Shale and lignite beds; in center a bright red-rust sandstone ledge	26½
27. Sandstone, light gray, weathers tan; fine-grained; thin-bedded (average bedding ¼ inch); weathers platy; underlain by gray, fine-grained limestone; weathers tan-orange	1
26. Sandstone, tan, weathers tan and reddish; friable; massive; overlain by woody shales; one and probably more lignite beds; several thin beds (1–3 inches) of limestone which weather rust-brown	68½
25. Covered interval including shale, sandstone and lignite; shales are woody or bony; weathers rusty; in middle is thin gray sandstone, weathers platy; lignite beds	34
24. Sandstone, gray, weathers reddish brown; thin-bedded; forms ledge	2
23. Covered; at top gray lithographic limestone; weathers orange-tan; nodular	9½
22. Sandstone, light tan, weathers light tan; thin-bedded; weathers to thin plates; distinct ledge	1½
21. Shales, mostly brown, woody shale; several lignite beds; near top a gray calcareous shale; some sandy shale and sandstone	91
20. Sandstone, gray, weathers buff with rust stain; ripple marks; forms definite ledge	2
19. Sandstone and shale; sandstone at base of unit is gray, fine-grained, thin-bedded; forms gray ledge; woody shales and several lignite beds above with nodular gray lithographic limestone in center; weathers rusty-red	84½
18. Covered tan clay slope; includes brown woody shale and lignite; petrified logs in lignite	6½
17. Sandstone, light gray, quartzitic; forms ledge; blocky	½
16. Shale, makes gray gumbo clay slope; contains nodules of gray, lithographic limestone	83½
15. Lignite	½
14. Sandstone, red, weathers buff	½
13. Sandstone, gray, weathers gray-white; might be some interbedded shale	45½
12. Shale, black, weathers white	½
11. Lignite	2
10. Shale, brown, woody	2
9. Sandstone with yellow shale partings; weathers gray	2
8. Sandstone and shale interbedded; base is tan, thin-bedded sandstone ledge; covered interval above, includes some black shale, probably lignitic; above is sandstone, tan, weathers brown with white stain; cavernous; massive; some fossil fragments; tan slope above, probably lignite bed and gray and brown shales; overlain by sandstone; weathers dirty green and reddish; olive-brown on fresh surface; above is another sandstone; weathers tan, whitish and brown on top of ledge; friable; fossiliferous; overlain by shale; at top is sandstone, tan; coarse-grained	58½

Unit	*Thickness (Feet)*
7. Shale, gray, some brown and woody and one or two coal beds; just above coal bed large *Ostrea soleniscus* weather out of brown shale	29½
6. Sandstone and shale; sandstone, gray, weathers gray and brown; friable, mostly thin-bedded; cross-bedded; near bottom is fossil zone containing *Ostrea soleniscus, Turbonilla coalvillensis, Turritella whitei, Mesostoma occidentalis;* shale, mainly gray; some sandstone is nodular; several layers of interbedded lignite; top bed gray, ripple-marked sandstone; weathers to thin, smooth-surfaced plates	243½
5. Sandstone gray, weathers gray and brown; very friable at bottom; slightly more resistant above; fossil fragments of oysters or *Inoceramus* (only small fragments); some snails and a shark tooth; mostly thin-bedded; cross-bedded	38
4. Partly covered; tan gumbo; thin lignitic coal bed	38
3. Lignite, shale, clay, sandstone; lignite bed (10 inches) overlain by banded shale; layers of gray cherty material between shales; weathers light gray, but brown on fresh surface; gray material resembles porcellanite; ripple-marked on top (3 inches); above is clay, gray gumbo; may be bentonitic; sandstone above is light gray and very fine-grained; has black specks which may be of volcanic origin (6 inches exposed); unit makes conspicuous white bed on hillside; more clay above, tan gumbo; white beds at top somewhat like the white sandstone but more shaly	14
2. Sandstone and shale; sandstone weathers gray and very irregularly, almost nodular; gray brown on fresh surface; a few fossil fragments in some beds	15
1. Sandstone ledge, weathers maroon; above is covered interval and then somewhat fossiliferous bed with small *Cardium;* at top dark brown shale overlain by poor lignitic coal bed probably about 10 inches thick	25
Total thickness	1,365

The coal in the Cody shale is lignite or sub-bituminous. The thickest seam observed was 3–4 feet thick, but most of the seams are only 8–10 inches thick. Many of the seams have numerous clay partings. The thickest coal seams occur near the top of the formation.

Fossils.—Most of the fossils found in the Cody shale have come from the lower part of the formation. A bed in unit 1 contains *Cardium,* probably *Cardium pauperculum.* Unit 2 contains a few unidentifiable fossil fragments. Unit 5 contains oyster fragments, *Inoceramus* fragments and shark teeth. From unit 6 *Ostrea soleniscus* Meek, *Turbonilla coalvillensis, Turritella whitei* and *Mesostoma occidentalis* were identified. Just above the first coal bed of unit 7 is a brown shale containing many large specimens of *Ostrea soleniscus.* (These fossils were all collected at Cole Hollow on the north side of the Gros Ventre River about 1 mile above Upper Slide Lake.)

The stratigraphic position of other fossils found at scattered localities in the Cody is not known. Near the mouth of Lava Creek on the west side just north of the main Togwotee Pass highway about 20 feet above the creek and above an abandoned and caved-in coal mine were collected the following.

Arca (*Barbatia*) *micronema* (Meek)
Perna sp.
Pedalion sp., aff. *P. wyomingensis* Henderson
Unio sp.
Cardium pauperculum Meek
Volutoderma ambigua (Stanton)?
Unidentified pelecypods
Unidentified gastropods

About ¼ mile east of Lava Creek above a coal mine along the main Togwotee Pass highway the following fossils were collected.

Arca (*Barbatia*) *micronema* (Meek)
Ostrea soleniscus Meek
Lima? sp. A
Volsella multilinigera Meek
Cardium pauperculum Meek
Unidentified pelecypods

Origin of name and distribution.—The Cody shale was originally described from a rock section near Shoshone River which consists of gray and dark shale with one bed of sandstone near the base and several thin fossiliferous sandstones near the top.[120] It was named from the town of Cody which is located on an outcrop of the formation. The name was carried over from the Bighorn Basin to the Wind River Basin and later to the northwest end of the Wind River Mountains. The use of the term in this paper constitutes its westernmost application. Richmond[121] has applied the term the farthest southwest to Cretaceous beds in the Green River area. It has been used as far north as southern Montana.

Age and correlation.—In the Bighorn Basin, the fauna of the Cody shale was shown by Stanton[122] to be of Coloradoan and Montanan age. In the Oregon Basin, Reeside[123] found that the lower part of the Cody shale has a fauna like that in the Niobrara of the Great Plains and contiguous areas, and like that in the middle of the Mancos shale of New Mexico, Utah and Arizona and in the upper part of the Colorado formation of Montana; the upper 350 feet of the Cody has a fauna of Eagle age.[124]

The fossils collected from the Cody in the Gros Ventre River area are not diagnostic. Such species as *Inoceramus umbonatus, Inoceramus exogyroides, Inoceramus deformis, Scaphites ventricosus* and *Scaphites vermiformis,* which Reeside considers to be good guide fossils for the lower Cody were not found. However, fossils are abundant at certain horizons in the Cody, and as a result, more extensive search will probably yield diagnostic fossils.

On the basis of stratigraphic position and lithology, it seems likely that the Cody in the Gros Ventre area corresponds in age with the Cody of the Bighorn Basin. The Cody of this area is probably correlative with the Hilliard formation of southwestern Wyoming. Among the fossils found by Schultz[125] in the Hilliard were *Ostrea soleniscus* and *Cardium pauperculum,* which are also found in the Gros Ventre River Cody. However, they are not diagnostic as both species commonly

[120] Charles T. Lupton, *op. cit.*, p. 166.

[121] Gerald M. Richmond, *op. cit.*

[122] Timothy W. Stanton, *op. cit.*, p. 120.

[123] J. B. Reeside, Jr., "Cephalopods from the Lower Part of the Cody Shale of Oregon Basin, Wyoming," *U. S. Geol. Survey Prof. Paper 150* (1927), p. 2.

[124] *Ibid.*, p. 1.

[125] Alfred R. Schultz, *op. cit.*, p. 65.

occur in the Frontier formation. The stratigraphic positions of the Cody and Hilliard are similar. Other correlations made with the Cody are shown in Figure 9.

MESAVERDE FORMATION

General description.—The Mesaverde formation overlies the Cody shale conformably. It is essentially a sandstone formation characterized by massive, buff-colored cliffs. Its total thickness in the area varies because of an unconformity at the top of the formation. The thickness along the Gros Ventre River near Cole Hollow is about 4,076 feet. This is probably about the maximum thickness for the region. The base of the Mesaverde formation was placed at the bottom of the first massive Mesaverde type sandstone which occurs above the highest lignite beds of the Cody.

Detailed section.—The following section of the Mesaverde formation was measured north of Cole Hollow in the Mount Leidy Quadrangle (Fig. 5).

Unit	*Thickness (Feet)*
13. (Beds are cut out in most places by unconformity.) Shales, at least two of the typical limestone beds and a slabby sandstone, weathering rust	100±
12. Sandstone, huge massive cliffs; appear white from distance; have typical brown ledge of sandstone on top	214½
11. Sandstone of same type as unit 12; probably forms huge cliff along side of ridge; near bottom of unit is calcareous gray sandstone and at bottom thin lignite bed	247½
10. Sandstone, perhaps a little interbedded shale; mostly massive with some thinner-bedded brown type as capping layers; nearly all are cliff-forming sandstones; some interbedded lignites and probably black shales	1,400±
9. Partly covered, probably sandstone and shale; top of ridge is tan sandstone, weathers light gray; friable; overlain by gray sandstone which weathers brown and red	45½
8. Sandstone and shale; ledges of gray calcareous sandstone, weathers rust-brown; interbedded calcareous shales which weather gray and orange; top is massive ledge of gray sandy limestone, weathers rust-brown and reddish; weathered surface has cross-bedded appearance; 2 feet plus exposed	131½
7. Partly covered; consists of calcareous shales with ledgers of gray calcareous sandstone, weathers rust-brown; a little friable tan sandstone; a little plant material but not abundant as below; no cliffs like those of unit 2, just ledges, except at top of unit where there is cliff like those below; lignite bed 35 feet from bottom and another lignite bed a few feet above the first	190½
6. Partly covered; includes beds of gray, fine-grained calcareous sandstone, weathers rust-brown; some orange, calcareous shale; sandstones contain leaves and other plant fragments; thin lignite bed at top of unit	131½
5. Sandstone and covered; covered interval at base overlian by sandstone ledge lithologically like previous cliff; several outcrops of light sandstone above are capped by rust-brown sandstone; top is gray lithographic limestone, weathers orange-brown; thin-bedded, breaks into small fragments	90½
4. Sandstone cliffs separated by covered intervals; cliffs are of tan friable massive sandstone; weather cavernously; each cliff commonly capped by layer of darker brown, more thinly bedded sandstone which is in places dolomitic; a few ledges of dark gray sandy limestone, weathers rust-brown, are interbedded in shale; lignite bed near top of section	503
3. Unit appears somewhat transitional between 2 and 4; sandstone becomes more massive, cliff-former and lighter in color; however, there are still ledges of reddish-weathering, thin-bedded sandstone	150½
2. Sandstones, shales and limestone; long series of alternating sandstones, limestones, and shales; no fossils observed, and rocks seem lithologically same throughout; some sandstones and limestones stand out as ledges while shales and friable sandstone probably make up most of covered intervals between; limestone is dark gray, lithographic, in places nodular; weathers tan to rust-color; in places on weathered surface has irregular banding like woody structure; weathers into irregular pieces and commonly highly fractured; sandstones of two types; a gray friable massive bed which may make up	

Unit	*Thickness (Feet)*
some of covered intervals; it is ordinarily overlain by thin-bedded (average ¼ inch) gray, more resistant sandstone; commonly weathers with dark maroon color; shales observed were dark gray and tan-brown	837
1. Sandstone; two massive sandstone cliffs separated by short covered interval; lower part of each cliff is massive tan sandstone, capped by thin-bedded more resistant brownish-weathering sandstone; lower part of cliffs weather cavernously; at base of second cliff is brown woody shale overlain by a few inches of lignite	34
Total thickness	4,076±

Characteristic Mesaverde type cliffs.—The two massive sandstone cliffs of unit 1 are of a type characteristic of the Mesaverde. The lower parts of the cliff consist of massive buff sandstone. It weathers irregularly, and numerous caves and hollows are common along the cliff face. The cliff is capped by a thin-bedded more resistant sandstone which weathers brown. This harder layer commonly projects over the lower part of the cliff which is composed of the more easily eroded and much lighter-colored sandstone. Wherever the Mesaverde crops out, it may be recognized by cliffs, formed by the two contrasting sandstones.

Sedimentation cycle.—Unit 2 presents an interesting sedimentation cycle. It consists of 837 feet of alternating shales, sandstones, and limestones. The sandstones and limestones ordinarily stand out as ledges, and the shales make up the covered intervals between.

The sandstones in the series are of two types: one is gray, friable, massively bedded sandstone, and the other is gray, weathering dark maroon, thin-bedded, and more resistant to weathering. The thin-bedded, maroon-weathering sandstone ordinarily overlies the massive, gray sandstone. The shales, which make up the covered intervals between ledges of sandstone and limestone are dark gray and light brown. The limestone is dark gray and weathers tan to rust-color. It is lithographic in texture and in places nodular. It also shows, in places, on the weathered surface, an irregular banding, resembling woody structure. It is commonly much shattered and breaks with a tendency to conchoidal fracture.

In all, 68 alternating beds of sandstone, shale, and limestone were counted in this unit. The alternations follow the general pattern here listed. Approximately 14 such cycles are present.

Top	*Thickness*
Limestone, ledge, gray, nodular, lithographic	10–18 inches
Covered slope, probably gray and tan shales	10–20 inches
Sandstone ledge, gray, weathers maroon, thin-bedded	2– 8 feet
Sandstone, gray, massive, friable, commonly weathers to covered slope	10–15 feet
Bottom	

In order to account for these alternations the source of the sediments must be considered. It is believed that the highland which furnished the sediments was at the west because at the east the sandstones change to marine shales and because no Upper Cretaceous deposits are known in the Great Central Cordillera.[126]

[126] J. B. Reeside, Jr., "Maps Showing the Thickness and General Character of the Cretaceous Deposits in the Western Interior of the United States," *U. S. Geol. Survey Prelim. Map 10*, Oil and Gas Inves. Ser. (1944).

The sandstone facies is generally considered to be mainly non-marine although in places there is interfingering of marine beds.[127] In the area described in this paper, no fossils were found in the beds belonging to the sedimentation cycle of unit 2, except a few plant fragments in one of the limestone beds near the top of the series of alternations. Leaves, other plant remains, and lignite seams have been found in higher units of the Mesaverde which probably indicate non-marine origin. Lignite seams also occur below unit 2. Ripple marks and cross-bedding are present in some of the sandstones. It seems likely therefore, that unit 2 is non-marine, although some of the beds may have had a marine origin.

PERIOD	NW. COLORADO *BARTRAM*	SW. WYOMING *RICHMOND*	SW. WYOMING *SCHULTZ*	GROS VENTRE MTS	CENTRAL WYOMING *BARTRAM*	BIG HORN BASIN *LUPTON*	BLACK HILLS & E. WYO *DARTON & BARTRAM*	
UPPER CRETACEOUS							PIERRE	
	MESAVERDE		? ADAVILLE	MESAVERDE	MESAVERDE	MESAVERDE		
	MANCOS	CODY	HILLIARD	CODY	STEELE	CODY	NIOBRARA	
		?			NIOBRARA		CARLILE	
					CARLILE		GREENHORN	
		FRONTIER	FRONTIER	FRONTIER	FRONTIER	FRONTIER	BELLE FOURCHE	GRANEROS
		?						
		MOWRY AND THERMOPOLIS	ASPEN	MOWRY	MOWRY	MOWRY	MOWRY	

FIG. 9.—Upper Cretaceous correlation chart.

The Gros Ventre River area is near the western margin of occurrence of the Mesaverde and its equivalents.[128] Thus the highlands furnishing the sediments may not have been far west. Wanless,[129] in discussing cyclic Pennsylvanian sediments, groups the cyclic sediments into three general types: the piedmont facies, the delta facies, and the neritic facies. The Mesaverde cyclic facies described here has certain similarities to the delta facies. Wanless[130] says that it is most typically

[127] *Ibid.*

[128] *Ibid.*

[129] Harold R. Wanless, "Sea Level and Climatic Changes Related to Late Paleozoic Cycles," *Bull. Geol. Soc. America*, Vol. 47, No. 3 (1936), p. 1182.

[130] *Ibid.*, p. 1184.

developed a few hundred miles from the high landmasses, which is the situation postulated for the Mesaverde. If the Mesaverde had been deposited nearer the landmass, some conglomerates and conglomeratic sandstones might be expected and none was found in unit 2. The order of the alternations in the Mesaverde is similar, in part, to the typical succession for the delta facies given by Wanless. At the base of the succession described by Wanless is a sandstone which is overlain by sandy shale grading upward into clay shale. This is overlain by impure limestone, generally non-fossiliferous and probably of non-marine origin. This much of the succession is very similar to that of the Mesaverde, although the rest of the series, which includes coal, is not present in unit 2.

Thus, the Mesaverde sediments may belong to a delta facies formed by material eroded from highlands a few hundred miles west. The cycles of deposition might have been due either to orogenic movements in those western highlands or to cyclic climatic changes. Uplift of the highlands on the west might have rejuvenated the streams resulting in the deposition of the sandstones. As the highlands became worn down, shale deposition replaced that of sandstone, and finally, when little or no clastic material was being brought in, limestones were laid down. These orogenic movements might have been forerunners of the Laramide orogeny which soon followed. It is difficult to explain a series of rhythmic orogenic movements. It seems more likely that the movements may actually have been progressive, rather than periodic. As effects of movements in the source region on distant sedimentation would not take place immediately, some cumulation of the effect might take place. Thus, progressive uplift might result in types of cyclic sedimentation.

The explanation of the sedimentation cycle by climatic changes is a possibility. The sediments are too thick to consider the cycles as due to seasonal or yearly changes. Climatic cycles of longer duration such as those indicated by repeated periods of continental glaciation might be responsible. Climatic cycles have been thought by some to be related to the sunspot cycle, precession of the equinoxes, and the eccentricity of the earth's orbit. Gilbert[131] suggested that the 21,000-year period of the precession of the equinoxes was responsible for a rhythmic effect noted in Upper Cretaceous strata of Colorado. However, it is not at all certain how these various cycles affect the climate.

Upper part of Mesaverde.—Unit 3 is transitional between unit 2 and the overlying part of the Mesaverde. Its lithologic character resembles the cyclic repetition of unit 2, but the sandstones are more massive, and some form cliffs of lighter color. Above unit 3, this type of cliff-forming sandstone predominates and is most massive near the top of the formation. In some places the massive sandstones are overlain unconformably by the Pinyon conglomerate. In one place, above the massive sandstone, were found ledges of thin-bedded sandstone, shale, and limestone.

[131] G. K. Gilbert, "Sedimentary Measurement of Cretaceous Time," *Jour. Geol.*, Vol. 3 (1895), pp. 121–27.

Origin of name Mesaverde.—The name Mesaverde was originally applied to a group of sandstone and coal beds in southwestern Colorado and northwestern New Mexico.[132] Subsequently the Mesaverde formation was identified and mapped across central Wyoming. As Reeside states,[133] the name Mesaverde has been used rather widely as a designation for a coal-bearing series in the upper part of the Upper Cretaceous. The name has been applied as far away from the type area as northern Wyoming. Reeside further states that the relations of the Mesaverde group of southwestern Colorado to beds similarly named in northern Colorado, Utah, and Wyoming are not at all clear. In some parts of Wyoming the base of the Montana group is definitely known and general relations of the Mesaverde group of those regions to the typical Mesaverde can be deduced, but not enough faunal evidence has been assembled to make detailed comparisons possible.

Since no other than a few non-diagnostic plant remains were found in the Gros Ventre area, the term Mesaverde has been applied here in the same manner as in other parts of Wyoming, without any definite knowledge of its relationship to the type area in Colorado. The name, although not a good one, is used because this formation is lithologically similar to, and in approximately the same stratigraphic position as, the so-called Mesaverde of the Bighorn Basin and central Wyoming.

The Mesaverde may be related to the Adaville of southwestern Wyoming, which is also a coal-bearing formation. However, the Mesaverde in the Gros Ventre area does not have outstanding coal beds, but only a few very thin lignite seams. The Mesaverde occupies the same stratigraphic position as the Gebo and Meeteetse formations described by Hewett[134] which occur along the Shoshone River. It has also been correlated with the Judith River formation of Montana.[135] Further correlations are shown in Figure 9.

CONCLUSIONS

The Paleozoic and Mesozoic sedimentary rocks of the northern Gros Ventre and Mount Leidy Highlands area are relatively thin as compared with those laid down on the west and southwest. This indicates that the area was probably a shelf zone bordering a deeper part of the Rocky Mountain geosyncline during most of the Paleozoic and Mesozoic eras. It was not the location of any of the deeper basins which received great thicknesses of sediments. However, all of the systems, with the possible exception of the Silurian, are represented. The study

[132] W. H. Holmes, *U. S. Geol. and Geog. Survey of Territories, Ninth Annual Report for 1875* (1877), pp. 245, 248.

[133] J. B. Reeside, Jr., "Upper Cretaceous and Tertiary Formations of the Western Part of the San Juan Basin, Colorado and New Mexico," *U. S. Geol. Survey Prof. Paper 134* (1924), p. 16.

[134] D. F. Hewett, "The Shoshone River Section, Wyoming," *U. S. Geol. Survey Bull. 541* (1912), p. 91.

[135] J. B. Reeside, Jr., *op. cit.* (1944).

of detailed stratigraphic sections of some of the formations resulted in the following conclusions.

1. Cambrian lithologic units and formations are persistent throughout the area and can be correlated with those of adjoining regions.

2. The so-called Bighorn dolomite may be a different formation from the type Bighorn; or, the Bighorn in western Wyoming may include more than one formation, and only part of the strata may be equivalent to the Bighorn farther east.

3. The Devonian rocks studied differ considerably in lithologic character where the sections were measured, and lithologic units could not be correlated.

4. The Frontier formation has a fauna similar to that found in the Frontier formation in other parts of Wyoming.

5. Upper Cretaceous rocks which are correlative with the Cody and Mesaverde formations of other parts of Wyoming are present.

6. The Mesaverde formation shows evidence of cyclic sedimentation.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 31, NO. 9 (SEPTEMBER, 1947), PP. 1594-1607, 7 FIGS.

UPPER ORDOVICIAN SHALES IN CENTRAL KANSAS[1]

HALL TAYLOR[2]
New York, N. Y.

ABSTRACT

Shales approximately equivalent in age to Maquoketa beds in Iowa and to Sylvan strata in Oklahoma form the topmost Ordovician over much of central Kansas. They normally consist of two members: (1) an upper dolomitic gray shale, which is siliceous and cherty in some areas, and (2) a lower soft flaky shale. These beds are thickest in the central part of the Salina basin and also in a belt extending north-south through western Harvey County. They disappear on the flanks of the Nemaha arch and of the Central Kansas uplift, probably because of truncation, and also thin and disappear in the region of northern Sedgwick County, probably because of non-deposition in places, coupled also with some truncation. Possible sources of the shaly material include the Central Kansas uplift, Ozark dome, and volcanic dust dropped by winds into the muddy upper Ordovician seas.

INTRODUCTION

Scope of paper.—Upper Ordovician shales occur in the subsurface over much of central Kansas. Normally they lie above the middle Ordovician Viola limestone and below Siluro-Devonian Hunton strata, both of which are oil reservoirs in some areas. They are approximately equivalent to the Maquoketa formation of northeastern Iowa, and to the Sylvan beds which crop out in Oklahoma, but exact subsurface correlations have not been determined. This paper describes the stratigraphy and structure of the beds, which are here called Maquoketa-Sylvan shales, and presents some interpretations of paleogeographic history, based on examination of samples and logs from several hundred wells. The map (Fig. 1) shows the area covered in this study, and the locations of most of the wells utilized.

Stratigraphic setting.—Surface rocks in central Kansas include strata of Quaternary, Cretaceous, Permian, and Pennsylvanian age. In the subsurface section Mississippian limestones disconformably overlie Chattanooga shales, which are of lower Mississippian and possibly upper Devonian age. Next come Misener sandstones and Hunton dolomitic limestones, both deposited in Siluro-Devonian time. Ordovician strata consist of Maquoketa-Sylvan shales at the top, under which are the Viola limestone, Simpson formation and Arbuckle dolomitic limestone. A basal sand resting on pre-Cambrian crystalline rocks completes the central Kansas section. The sedimentary deposits are several thousand feet thick, although no single area has a complete section.

Names of these subsurface formations are borrowed from outcrops which occupy approximately corresponding stratigraphic positions, but exact correlations between surface and subsurface areas have not been published. The upper Ordovician shale of central Kansas is believed to be continuous in the subsurface

[1] Manuscript received, June 5, 1946; revised manuscript, June 10, 1947.

[2] Instructor in geology, Columbia University. Among those whose interest was helpful during preparation of this paper are Professor Marshall Kay of Columbia University, Professor R. C. Moore, director of the Kansas Geological Survey, and Robert Carmody of the Gulf Oil Corporation. Conclusions herein stated are the writer's own, and do not necessarily reflect views held by those named. To all who helped in the preparation of this paper the writer extends sincere thanks.

with both the Maquoketa and Sylvan formations, although perhaps not exactly equivalent to either. In that case present names are incorrect, but until definite and exact correlations with surface outcrops are established, the present names, which are in current use, are best retained.

Subsurface structural elements.—The Maquoketa-Sylvan shales discussed in this paper lie between the Nemaha granite ridge on the east and the Central Kansas uplift on the west (inset, Fig. 1). The Nemaha arch is a ridge of crystalline rocks trending northeast-southwest across east-central Kansas. It rose in early Pennsylvanian time. Maquoketa-Sylvan beds, although now missing from the crest of the structure, were probably once continuous over the area.

The Central Kansas uplift, in west-central Kansas, was a positive platform during early Paleozoic time. Its flanks were at least partly covered with Ordovician sediments, including Maquoketa-Sylvan shales, but pre-Pennsylvanian erosion removed many of these beds from the higher parts of the uplift, and left the main body of upper Ordovician shales some distance out on the flanks, and in the Salina basin on the east.

The term Salina basin is applied to the area between the Nemaha arch and the Central Kansas uplift in McPherson County and northward. Minor folds have warped beds within the basin, and influenced the location of some oil pools. The basin extends into Nebraska, but its northern limits have not been accurately defined.

Previous publications.—Little detailed information regarding Ordovician strata in central Kansas has been published. Much work has been done by oil companies during the last 20 years, but the results normally have not been released. Published material includes papers by Barwick,[3] Edson,[4] Kay,[5] McClellan,[6] Hiestand,[7] Rich,[8] Koester,[9] Bunte,[10] Dott,[11] Lee,[12] Leatherock,[13] Carmody,[14] and Taylor.[15]

[3] John S. Barwick, "The Salina Basin of North-Central Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 2 (February, 1928), pp. 177–99.

[4] Fanny Carter Edson, "Pre-Mississippian Sediments in Central Kansas," *ibid.*, Vol. 13, No. 5 (May, 1929), pp. 441–58.

[5] G. Marshall Kay, "Correlatives of Mohawkian Sediments in Kansas," *ibid.*, Vol. 13, No. 9 (September, 1929), pp. 1213–14.

[6] Hugh W. McClellan, "Subsurface Distribution of Pre-Mississippian Rocks of Kansas and Oklahoma," *ibid.*, Vol. 14, No. 12 (December, 1930), pp. 1535–56.

[7] T. C. Hiestand, "Voshell Field, McPherson County, Kansas," *ibid.*, Vol. 17, No. 2 (February, 1933), pp. 169–91.

[8] John L. Rich, "Distribution of Oil Pools in Kansas in Relation to Pre-Mississippian Geology," *ibid.*, Vol. 17, No. 7 (July, 1933), pp. 793–815.

[9] Edward A. Koester, "Geology of Central Kansas Uplift," *ibid.*, Vol. 19, No. 10 (October, 1935), pp. 1405–26.

[10] Arnold S. Bunte, "Subsurface Study of Greenwich Pool, Sedgwick County, Kansas," *ibid.*, Vol. 23, No. 5 (May, 1939), pp. 643–62.

[11] Robert H. Dott, "Regional Stratigraphy of Mid-Continent," *ibid.*, Vol. 25, No. 9 (September, 1941), pp. 1619–1705.

GENERAL SURVEY

Stratigraphy.—Two different types of shaly strata comprise the Maquoketa-Sylvan formation over much of central Kansas. One, here called the upper shale member, is normally hard gray shale containing varying amounts of dolomite crystals and rhombs whose molds make residues very dolocastic. In parts of central Kansas this member contains sufficient siliceous material to produce hard gritty fragments, and some wells even show dirty gray silty cherts intermixed with the dolomitic shales. These silty chert-like pieces are commonest in the northeastern and southwestern parts of the central Kansas area.

The other member, here termed the lower shale, underlies the upper dolomitic shale, and is soft, flaky, gray and silty in the north, but grades into darker gray, brown and even black shale in the south. It is relatively non-dolomitic, and residues are only sparingly dolocastic. Most geologists, including the writer, place this shale section in the upper Ordovician, but some years ago Johnston[16] put it in the Silurian, and Ver Wiebe[17] has recently suggested it belongs in the Kinderhook.

Neither of these shale members breaks into long slender angular fragments as do some beds in the Chattanooga, nor do they have the green waxy appearance of much typical Simpson shale. Either may be missing from wells in which the other is represented. Sharp contacts between them are rare, but holes drilled in shale are subject to considerable caving, and contacts may be sharper than appears from the samples. In a few wells the change from dolomitic to non-dolomitic strata is sharply defined, but in most tests it is spread over at least a 20-foot interval. Large fragments collected near the contact in some wells show silty chert layers or thin dolomitic siliceous shale seams interfingering with soft non-dolomitic shale layers, suggesting a gradual merging of the upper and lower strata.

Over much of central Kansas calcareous Hunton beds separate Maquoketa-Sylvan from Chattanooga shales, thus facilitating separation of these formations on the basis of lithology. But in some areas where Hunton strata are absent the Ordovician and Mississippian shales lie in contact. Such a situation exists in central Marion, central and northwestern McPherson, southwestern Saline, and

---

[12] Wallace Lee, "Stratigraphy and Structural Development of the Forest City Basin in Kansas," *Kansas Geol. Survey Bull. 51* (December, 1943). 142 pp.

[13] Constance Leatherock, "Correlation of Rocks of Simpson Age in North-Central Kansas and Northwestern Missouri," *ibid., Bull. 60* (June, 1945). 16 pp.

[14] R. A. Carmody, "Kinderhook Dolomite of Sedgwick County, Kansas" (discussion), *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 31, No. 1 (January, 1947), pp. 150–60.

[15] Hall Taylor, "Middle Ordovician Limestones in Central Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 31, No. 7 (July, 1947), pp. 1242–82.

[16] Leslie A. Johnston, "Pre-Pennsylvanian Stratigraphy of the Hollow Pool," *Tulsa Geol. Society Digest*, Vol. 3 (1934), p. 12.

[17] W. A. Ver Wiebe, "Kinderhook Dolomite of Sedgwick County, Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 30, No. 10 (October, 1946), pp. 1747–55.

eastern Ellsworth counties. Here driller's logs are useless in mapping Maquoketa-Sylvan shales; and although most layers of the black or dark gray spore-bearing Chattanooga shale differ lithologically from Maquoketa-Sylvan strata, sample examination is of doubtful value, especially in rotary wells, because of contamination through caving. However, the few clean cuttings available indicate that upper Ordovician shales are thin or missing, and most of the shale section is Chattanoogan. This is not surprising, since harder calcareous Hunton strata did not protect the easily eroded Ordovician shales during the pre-Chattanoogan erosion interval.

Structure.—Maquoketa-Sylvan beds vary in thickness, but do not exceed 100 feet over most of central Kansas (Fig. 1). They thin southeast (Fig. 2), and disappear in northwestern Butler and northern Sedgwick counties. They are gone on parts of the Nemaha granite ridge, but are present east of that structure. They are missing from most of the Central Kansas uplift, having been truncated on the flanks by pre-Pennsylvanian erosion. They thicken to more than 100 feet in Ottawa County, and continue for an undetermined distance northward in the Salina basin.

The isopachal map (Fig. 1) should be regarded as a progress report rather than a finished map. Thicknesses determined through examination of samples are considered reliable, but the isopach lines in many areas are located partially through records on driller's logs. Some of these are accurate; many are misleading, and subject to various interpretations. In examining such records there commonly are very few clues to indicate which logs state facts and which are merely words on paper. In mapping the Maquoketa-Sylvan shale, driller's logs were used if they appeared reasonable by comparison with the nearest sample wells, otherwise they were usually disregarded. Isopachs based on such logs will be subject to material revision as information is gathered from additional wells.

Dips of the shales are gentle except in a few folded areas where the beds are steeply tilted or faulted. For example, at the south end of the Hollow-Nikkel pool in northwestern Harvey County (Sec. 30, T. 22 S., R. 3 W.) the tops of identical beds vary more than 200 feet within distances of $\frac{1}{4}$ mile.

The oil-productive Voshell anticline in western Harvey County lies on the site of a comparatively thick Maquoketa-Sylvan shale section. It is interesting to note that this area which contains relatively thick deposits of upper Ordovician shales is the same region which was deformed by minor faulting and folding in a later geologic period.

Paleogeography.—In central Kansas the upper Orodovician was a time of shallow, muddy, shale-depositing seas, following a long period of middle Ordovician limestone (Viola) deposition. The source of these extensive mud deposits is uncertain. They are too widely distributed to represent only near-shore erosion products of a continental sea, and they contain little or no coarse material characteristic of such deposits.

Perhaps some of the shale came from erosion of the Ozark dome which was a

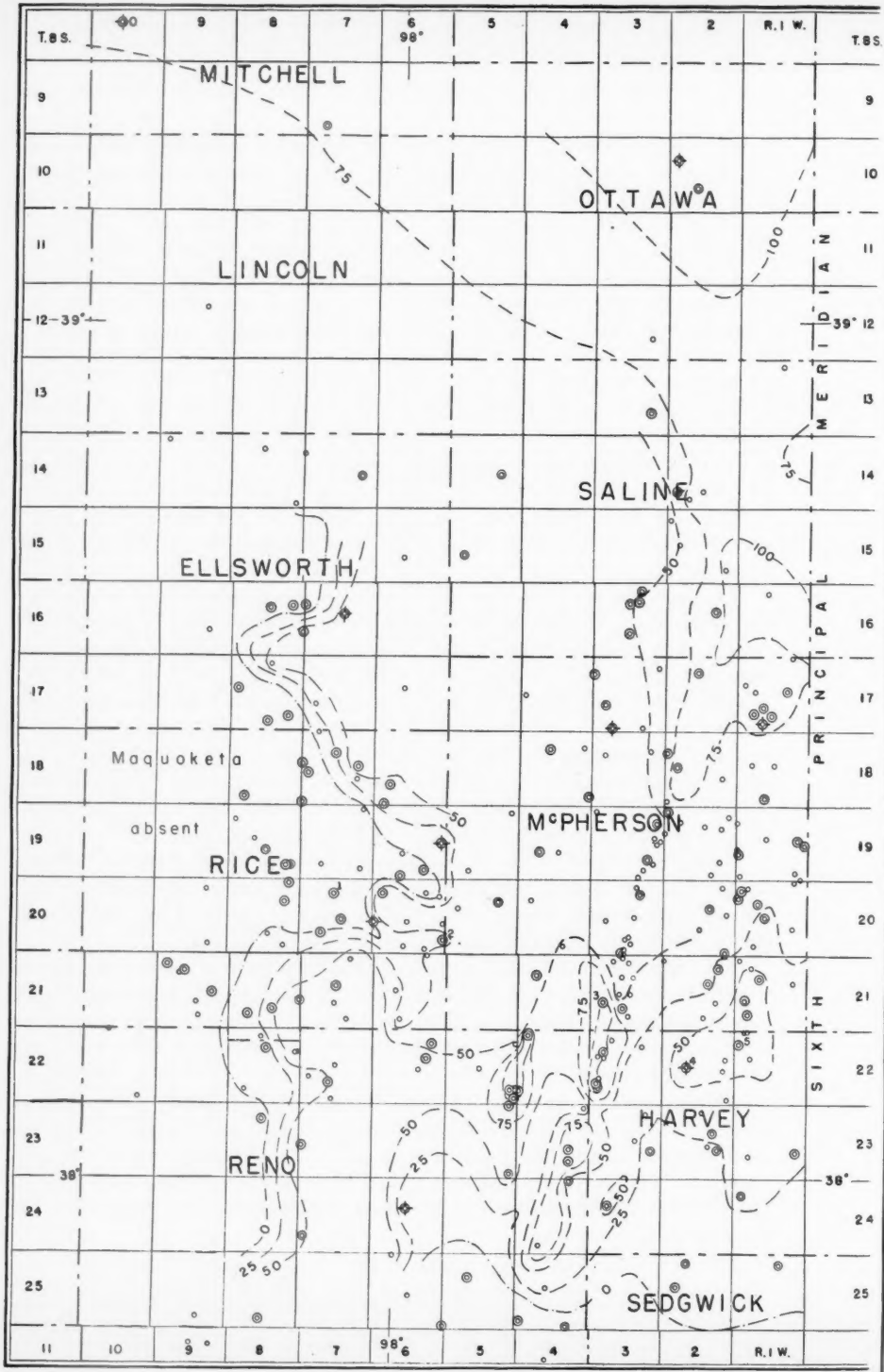
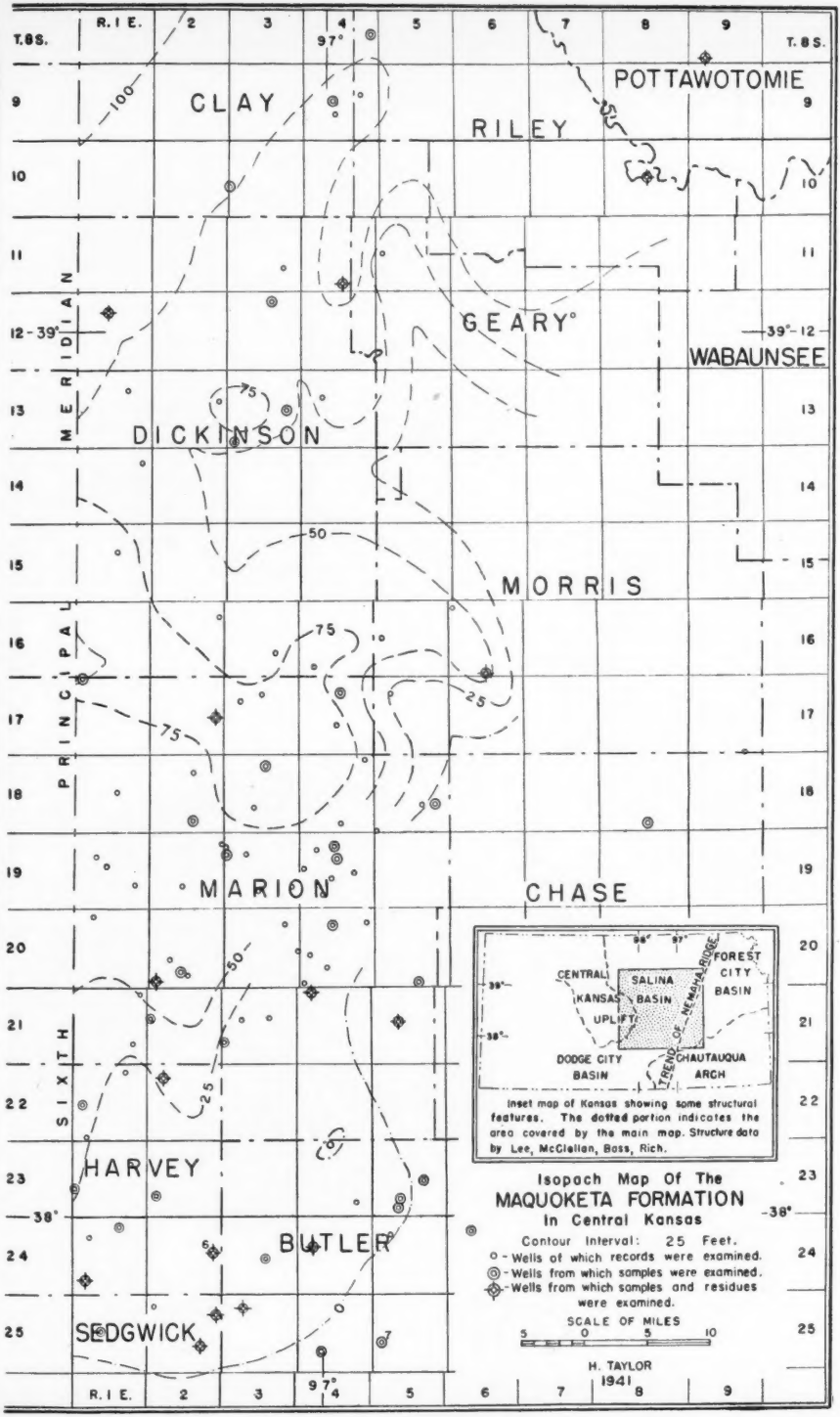


FIG. 1.—Isopach map of Maquoketa-



Sylvan formation in central Kansas.

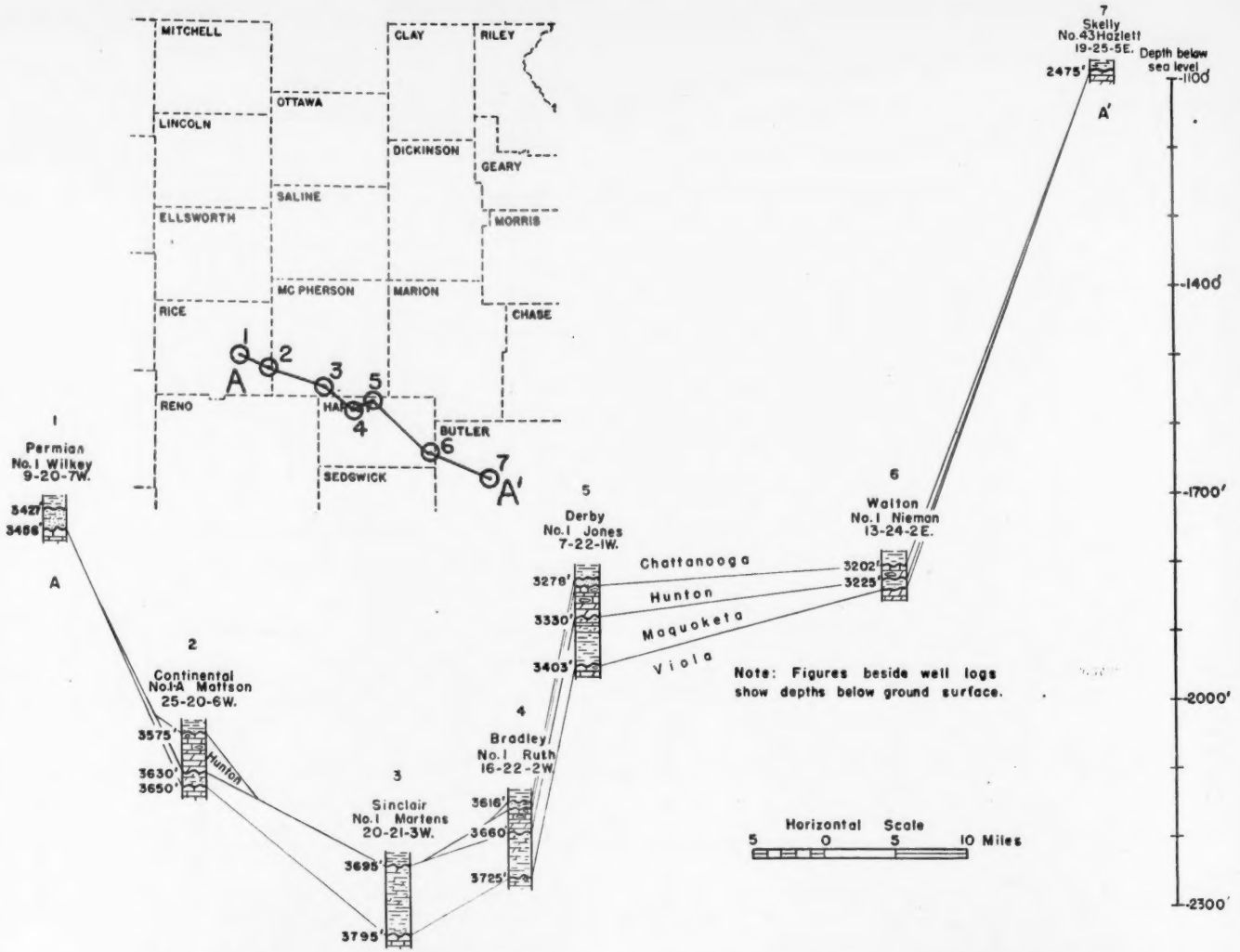
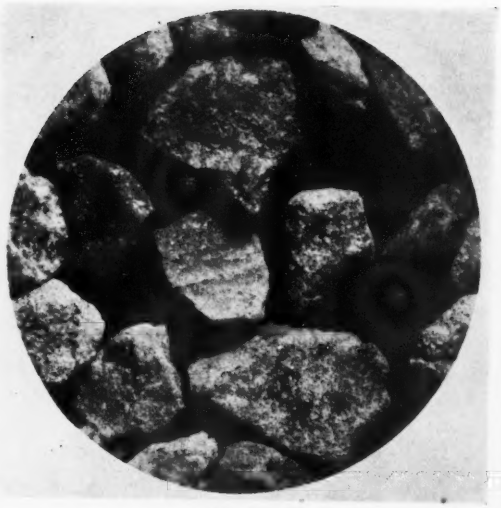


FIG. 2.—Geologic cross section of Maquoketa-Sylvan strata along line *AA'* (see inset index map) in north-central Kansas.

FIG. 2.—Geologic cross section of Maquoketa-Sylvan strata along line *AA'* (see inset index map) in north-central Kansas.



Original Sample

Residue

FIG. 3.—Photomicrographs (×12) showing dolomitic siliceous shale and chert of upper member of Maquoketa-Sylvan formation. From Umscheid well No. 1, Sec. 32, T. 8 S., R. 9 E., Pottawatomie County, depth 1,669–1,675 feet.

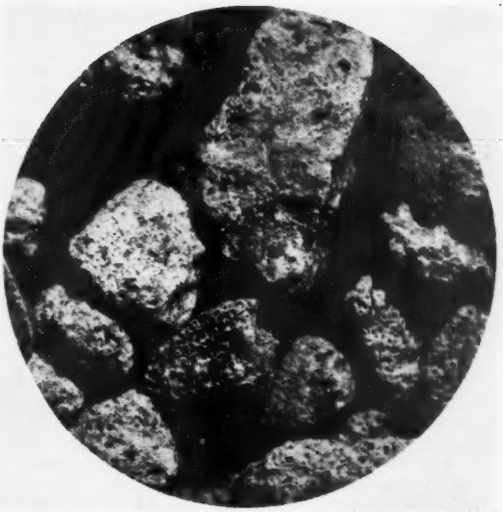


FIG. 4.—Photomicrograph (×12) showing very dolocastic residue of one facies of upper member, Maquoketa-Sylvan formation. From Umscheid well No. 1, Sec. 32, T. 8 S., R. 9 E., Pottawatomie County, depth 1,730–1,735 feet.

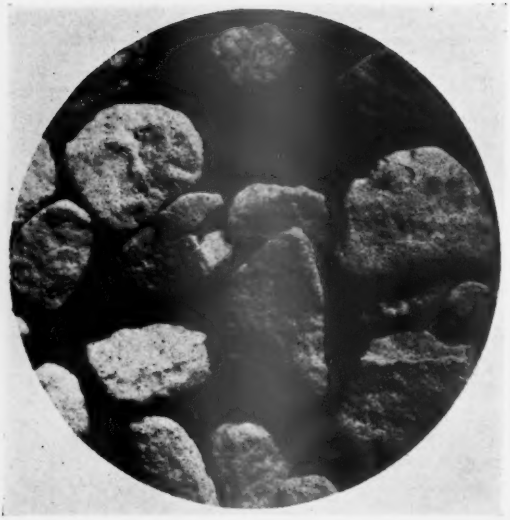


FIG. 5.—Photomicrograph (×12) showing minutely dolocastic siliceous shale residue of one facies of upper member, Maquoketa-Sylvan formation. From Danz well No. 1, Sec. 34, T. 11 S., R. 4 E., Dickinson County, depth 2,682–2,686 feet.

FIG. 6.—Photomicrograph (×12) showing flaky gray and brown shale residue of lower member, Maquoketa-Sylvan formation. From Copeman well No. 1, Sec. 7, T. 10 S., R. 2 W., Ottawa County, depth 3,490–3,497 feet.

FIG. 7.—Photomicrograph (×12) showing dolocastic residue of Maquoketa-Sylvan shale in southeastern part of central Kansas. Note traces of stratification in some fragments. From Boller Well No. 1, Sec. 29, T. 24 S., R. 1 E., Harvey County, depth 3,558–3,561 feet.

positive area at the southeast, and some may have been derived from the Central Kansas uplift on the west. But the latter region was at least partly covered by limestones of Viola seas, and was not extensively uplifted in the Ordovician.

A third possible source of material, and one whose quantitative effect is difficult to determine, is volcanic dust. Middle Ordovician volcanic ash deposits have been recognized in many parts of eastern North America. Possibly later in the Ordovician, volcanic dust fell in central Kansas and mixed with the shale deposits of Maquoketa-Sylvan seas.

The absence of evidence of stream dissection of the shales indicates that, following their deposition, the land remained near base level. Later came transgression of Siluro-Devonian Hunton seas from the east and northeast, with deposition of widespread calcareous beds. Formation of Misener sands of varying thicknesses occurred concurrently with, and subsequent to, Hunton deposition.

Slight tilting, followed by peneplanation, removed some Maquoketa-Sylvan deposits, and preceded deposition of Chattanooga shales. Then came formation of thick Mississippi limestones. Finally, a period of erosion preceded the deposition of Pennsylvanian strata, which form a cover that has remained in place to the present time, and has preserved what now remains of pre-Pennsylvanian beds.

DICKINSON COUNTY AND ADJACENT AREAS NORTHEAST

Stratigraphy. —In the northeastern part of central Kansas the Maquoketa-Sylvan formation exhibits a two-fold division. The upper member can not adequately be described by any single rock name. It is a dolomitic siliceous silty shale which is dirty gray in color, and which grades in some wells into a moderately hard silty chert. Both the shale and chert facies are dolomitic, and residues characteristically exhibit many dolocasts, some fragments being so spongy and porous after treatment with acid that they are easily crushed. Beneath this is the lower member which is non-siliceous, only sparingly dolomitic, and consists largely of light to medium gray soft flaky shale. The contact between upper and lower beds is abrupt in some wells, gradual in others.

In a few wells a dolomitic shale somewhat resembling the upper member, except for absence of chert, appears beneath the lower non-dolomitic member. As it is irregular in occurrence, and was not observed except in parts of this northeastern area, it is not given further consideration.

The upper member is an exceptional sort of material. Under the microscope original samples appear to be dolomitic gray shales and cherts, and residues are dolocastic (Fig. 3). If the fragments are scratched, some pieces are so hard they scrape bits of metal from the needle or knife just as would chert, but by repeated scratching, deep grooves can be made in them, something that would be impossible with true chert. Furthermore, the fragments do not break so easily as ordinary shale, and if crushed between the teeth they feel like very fine-grained gritty sand. Yet little graininess is apparent under the microscope. In residues, the pieces from some wells are honeycombed with dolocasts of all sizes, and are spongy and porous (Fig. 4), whereas others are solid or contain only small dolo-

casts (Fig. 5). Mixed with this material in some samples are aggregates of pink and gray dolomite crystals, plus some pyrite and colorless quartz.

The lower member of the Maquoketa-Sylvan formation is soft gray flaky shale which commonly is only slightly calcareous, and is not gritty. Small black carbonaceous specks, possibly graptolite fragments, appear in places. Some pieces of the shale slake in air, covering their uneven surfaces with fine light gray soft shaly powder. Such pieces, if dropped in water, swell with slight effervescence to about twice normal size and disintegrate into fine mud, all within a few seconds. This is characteristic of many clays and bentonites.

Residues of this lower member consist of soft flaky light tannish gray fragments which lack the fissility as well as the spores of the Chattanooga shale, and are so soft they are likely to crumble into small irregular flakes if touched. Surfaces are rough and irregular, quite in contrast to the flat or slightly curving surfaces seen on some Chattanooga shale. Bits of pyrite and quartz are present in some samples, and in residues a few small dolocasts appear. Abundant but very minute flakes of white mica give many pieces a sparkling appearance in reflected light.

Structure.—Thicknesses of the Maquoketa-Sylvan formation and of its upper and lower members vary from place to place, from 50 to 100 feet in most wells. The upper siliceous silty layers commonly constitute somewhat less than half of the section. The beds rise gently toward the east, but thin and disappear near the crest of the Nemaha ridge, as a result of late Paleozoic uplift and erosion of that structure.

MARION COUNTY

Stratigraphy.—Maquoketa-Sylvan shales in northern Marion County resemble those in near-by Dickinson County, except that the upper siliceous silty and cherty beds are thinner and even missing in places. In central Marion County Hunton strata are absent, Ordovician and Mississippian shales are in contact, and the complete shale section commonly exceeds 200 feet in thickness, most of it being dense dark gray fissile Chattanoogan material, with dolomitic gray Maquoketa shale appearing near the bottom in some wells. In southern Marion County Hunton strata reappear and overlie varying amounts, up to about 50 feet, of dolomitic and flaky, gray and brown Maquoketa shale.

A representative Marion County well is the Empire Oil and Refining Company's Bartel No. 1 (NW. $\frac{1}{4}$, SE. $\frac{1}{4}$, Sec. 31, T. 20 S., R. 2 E.), drilled at a point where Hunton strata are absent. However, clean samples permit separation of Maquoketa from Chattanooga strata. The log follows.

EMPIRE OIL AND REFINING COMPANY'S BARTEL NO. 1

Depth (Feet)	*Description of Zones*
2,700	TOP OF MISSISSIPPIAN LIMESTONE
2,870	TOP OF CHATTANOOGA SHALE
3,025	BASE OF CHATTANOOGA SHALE
3,025–3,080	MAQUOKETA-SYLVAN SHALE. Gray dolomitic shale (residues very dolocastic) with some flaky non-dolomitic shale in lower part. Small amounts of pyrite, gray drusy quartz and green glauconite occur at about 3,080 feet
3,080	TOP OF VIOLA LIMESTONE. Crystalline calcitic and dolomitic limestone

Structure.—Maquoketa-Sylvan shales thin toward the east and southeast in the direction of the Nemaha arch, and are missing in some wells near the crest of that structure. Normally they dip gently west, reflecting the tilt received through rise of the Nemaha ridge in early Pennsylvanian time.

SALINE COUNTY AND ADJACENT AREAS NORTH AND WEST

Stratigraphy.—In Saline, Ottawa, southern Mitchell, and eastern Ellsworth counties Maquoketa-Sylvan beds normally consist, as in the area on the east, of an upper dolomitic gray shale which in residues forms many dolocastic pieces, and a lower comparatively non-dolomitic flaky gray or brownish gray shale (Fig. 6) which is sparingly dolocastic in residues. The siliceous shale and silty chert of upper beds in areas at the east are gone, having graded into a softer shale which retains its gray and pink dolomite rhombs, but ordinarily lacks the hardness to scrape bits of steel from a needle which scratches it. The lower non-dolomitic shale exhibits no major change, although brownish-colored layers increase somewhat toward the west and south.

In Saline County a typical section is exhibited by the Lario *et al.* Fulton well No. 1 (SW. ¼, NW. ¼, Sec. 14, T. 16 S., R. 2 W.), in which 92 feet of Maquoketa-Sylvan beds are logged as follows.

LARIO ET AL. FULTON NO. 1

Depth (Feet)	*Description of Zones*
3,353	TOP OF MAQUOKETA-SYLVAN SHALES
3,353–3,383	UPPER DOLOMITIC SHALE MEMBER. Light gray shale with many embedded tan and gray dolomite crystals and rhombs. Residues very dolocastic
3,383–3,445	LOWER SHALE MEMBER. Gray and brownish gray soft flaky shale containing a few widely scattered dolomite crystals and rhombs. Residues sparingly dolocastic
3,445	TOP OF VIOLA LIMESTONE

In this Fulton well No. 1, as in most holes, the contact between the upper dolomitic shale and the lower non-dolomitic layers is not so sharp as appears on a log, and samples show fragments of both dolomitic and non-dolomitic shales for some distance on both sides of the contact.

Two wells in central Ottawa County indicate the Maquoketa-Sylvan section is about 100 feet thick in that area, and consists of an upper dolomitic gray shale, and a lower gray flaky shale which contains a few widely scattered dolomite crystals and rhombs.

Samples were examined from two wells in Mitchell County. In the southeast, Gurley's Abercrombie well No. 1 (NW. ¼, NE. ¼, Sec. 32, T. 9 S., R. 7 W.) contains about 90 feet of cherty dolomitic Hunton limestones which separate approximately 80 feet of underlying Maquoketa-Sylvan dolomitic shale from about 60 feet of overlying Chattanooga shale. In the southwestern part of the county, Hunton strata are missing in the Siedhoff *et al.* Grief well No. 1 (SW. ¼, SE. ¼, Sec. 16, T. 8 S., R. 10 W.), and the Chattanooga and Maquoketa-Sylvan shales, if both are present, are together in a single shale section which is approximately 100 feet thick. Only a few fragments from samples near the base of this section

resemble Maquoketa-Sylvan strata farther east. It is considered likely that upper Ordovician shales are very thin or absent in southwestern Mitchell County.

In Ellsworth County at least two wells near the edge of the Central Kansas uplift are believed to contain Maquoketa-Sylvan shales. Correlations with strata at the east are based solely on lithology, with gaps of many miles between wells, and some geologists do not agree with the interpretations here advanced. These wells are the Mid-Kansas Oil and Gas Company's Kanak No. 1 (NE. ¼, SW. ¼, Sec. 15, T. 16 S., R. 7 W.) and the Cities Service Oil Company's Essick No. 1 (NE. ¼, NE. ¼, Sec. 25, T. 16 S., R. 8 W.), whose partial logs are given here for check and comparison by others working in the area.

MID-KANSAS OIL AND GAS COMPANY'S KANAK NO. 1

Depth (Feet)	*Description of Zones*
3,023	BASE OF PENNSYLVANIAN. Varicolored shales and red cherty rock
3,023–3,082	MAQUOKETA-SYLVAN SHALES. Gray dolomitic shale which in residues is very dolocastic, grading downward into some very dark gray sparingly dolomitic shale
3,082	TOP OF VIOLA LIMESTONE. Light tan coarsely crystalline limestone

CITIES SERVICE OIL COMPANY'S ESSICK NO. 1

3,280	BASE OF PENNSYLVANIAN. Varicolored shales and cherts
3,280–3,340	MAQUOKETA-SYLVAN SHALES. Gray siliceous silty dolomitic shale grading downward into dark blue-gray non-dolomitic shale
3,340	TOP OF VIOLA LIMESTONE. Tan coarsely crystalline limestone

Structure.—The scattered wells from which samples were available in this area indicate that Maquoketa-Sylvan beds normally are between 50 and 120 feet thick. They dip gently into a trough whose axis extends north and south through western Saline and Ottawa counties, the dip being westerly for beds east of the axis, and *vice versa*.

Maquoketa-Sylvan beds occur considerably farther southwest than do the overlying Siluro-Devonian Hunton strata, being present in some wells in central Ellsworth County. But these shales have not been recognized in all wells where Hunton beds are missing, and the shale section overlying the Viola limestone may in some wells belong largely or entirely in the Chattanooga.

In Ts. 16 and 17 S., Rs. 7 and 8 W., the Maquoketa-Sylvan shales, Viola limestones, and Simpson sands and shales are tilted and truncated on the flanks of the Central Kansas uplift. The beds originally extended farther west, but post-Ordovician rise of the uplift has resulted in erosion of these deposits. Viola and Simpson beds do extend farther west in some places north and south of this area, and Maquoketa-Sylvan shales may do likewise in scattered outliers.

MCPHERSON AND RICE COUNTIES

Stratigraphy.—Over much of McPherson and Rice counties Hunton strata are absent, and Chattanooga and Maquoketa-Sylvan shales form a continuous section, in which separation of the two formations is difficult. Here as elsewhere most wells examined indicate that pre-Chattanooga erosion removed much of the upper Ordovician shale, and the thick argillaceous sections now present are

largely of Chattanooga age. On the map (Fig. 1) isopach lines have not been drawn across this region.

In the Maquoketa-Sylvan shale, where it can be recognized and separated with certainty, there is commonly the two-fold division of an upper dolomitic gray shale which in places is a siliceous silty sort of material, and a lower comparatively non-dolomitic gray shale. The two members change gradually, one to the other. They thin toward the west, become darker gray and brown, less dolomitic, and are not separable into two members.

In parts of McPherson and Rice counties a cherty bed, here placed in the Viola, immediately underlies the Maquoketa-Sylvan shales, and is considered part of those shales by some geologists. Its thickness varies to a maximum of about 75 feet, and its lithologic character shows facies changes from tan chert-bearing limestone to gray cherty shale. The cherty limestone facies is represented by the McPherson Oil and Gas Company's Norling well No. 1 (center of NE. $\frac{1}{4}$, Sec. 9, T. 17 S., R. 2 W.), and the argillaceous cherty facies by the Mid-Plains Oil Corporation's Newkirk test No. 1 (SW. $\frac{1}{4}$, SE. $\frac{1}{4}$, Sec. 14, T. 18 S., R. 7 W.), brief logs of which are here given.

McPherson Oil and Gas Company's Norling No. 1

Depth (Feet)	*Descriptions of Zones*
3,450	CONTACT OF HUNTON DOLOMITIC LIMESTONE WITH MAQUOKETA-SYLVAN DOLOMITIC SHALE
3,450–3,481	UPPER DOLOMITIC MEMBER OF MAQUOKETA-SYLVAN SHALE. Gray shale containing many embedded dolomite rhombs. Grades downward at about 3,480–85 feet into comparatively non-dolomitic gray shale
3,481–3,550	LOWER SHALE MEMBER OF MAQUOKETA-SYLVAN. Soft gray shale. Some pyrite. Considered base of Maquoketa formation
3,550	TOP OF CHERTY LIMESTONE BEDS. Brown microfossiliferous chert and brown crystalline limestone. Tentatively placed in Viola

Mid-Plains Oil Corporation's Newkirk No. 1

3,250–3,290	MISENER SANDSTONE
3,290–3,305	MAQUOKETA-SYLVAN SHALES. Gray somewhat dolomitic shale
3,305	TOP OF ARGILLACEOUS DOLOMITIC CHERTY BEDS. Chert is dirty gray, rough, and contains black specks which may be graptolite fragments. Tentatively placed in Viola

In some wells these cherty beds are so argillaceous that it scarcely appears logical to place them in the Viola instead of the Maquoketa-Sylvan. But they can be traced laterally into nearly pure cherty limestones where it seems even more illogical to place them in the overlying shale formation. Consequently, they are here called Viola, although correlations with surface outcrops are unknown.

Structure.—Upper Ordovician shales dip gently into a trough whose axis trends north-south across west-central McPherson County. They are thickest and farthest below sea-level in this same area (Fig. 2). The beds are truncated on the flanks of the Central Kansas uplift in eastern Rice County; and in southeastern McPherson County they begin a regional thinning which culminates in their disappearance in Butler and Sedgwick counties. They are faulted and folded locally on such structures as the Voshell anticline.

WESTERN HARVEY, RENO, AND NORTHWESTERN SEDGWICK COUNTIES

Stratigraphy.—Near the Sixth Principal Meridian in central Harvey and northern Sedgwick counties the Maquoketa-Sylvan beds are dark gray or grayish brown, comparatively thin, and only moderately dolomitic. Toward the west and northwest they thicken somewhat and assume the characteristic two fold division, with gray siliceous dolomitic argillaceous strata grading downward into gray or brown relatively non-dolomitic shales. Two wells illustrating this relationship are Connel and Slick's Wyatt No. 1 (SE. ¼, SE. ¼, Sec. 3, T. 25 S., R. 1 W.) near the meridian, and the Magnolia Petroleum Company's Schmidt No. 4 (NW. ¼, NE. ¼, Sec. 30, T. 22 S., R. 3 W.) about 20 miles northwest.

CONNEL AND SLICK'S WYATT NO. 1

Depth (Feet)	*Descriptions of Zones*
3,600	BASE OF HUNTON STRATA
3,600–3,616	MAQUOKETA-SYLVAN SHALE. Soft flaky resinous-looking brown and gray shale
3,616	TOP OF VIOLA LIMESTONE

MAGNOLIA PETROLEUM COMPANY'S SCHMIDT NO. 4

3,370	TOP OF MAQUOKETA-SYLVAN STRATA
3,370–3,440	UPPER DOLOMITIC MEMBER. Gray siliceous dolomitic shale. Residues show two interfingering types of material: (1) tan, minutely and abundantly dolocastic, gritty siliceous shale intermixed with (2) gray sparingly dolocastic soft shale
3,440–3,476	LOWER SHALE MEMBER. Dark gray, hard, slightly dolomitic (at some horizons) shale
3,476	TOP OF VIOLA LIMESTONE

Over much of Reno County the Maquoketa-Sylvan section is a uniform gray and brown moderately dolomitic shale which is not readily separable into upper and lower units.

Structure.—Maquoketa-Sylvan strata thin and disappear in central Reno County. Isopachs shown in Figure 1 are based on comparatively few wells, and will be subject to revision as additional information becomes available. The strata also are gone toward the south in parts of Reno and Sedgwick counties. At least one well in the extreme south part of the area covered in this report appears to have Chattanooga shale resting on Simpson sands. This is the Empire Company's Mueller hole No. 1 (center of SW. ¼, Sec. 35, T. 25 S., R. 4 W.), with the Chattanooga-Simpson contact at 4,094 feet.

EASTERN HARVEY, BUTLER, AND NORTHEASTERN SEDGWICK COUNTIES

Stratigraphy.—In the southeastern part of central Kansas the Maquoketa-Sylvan shales become darker gray, brownish gray and even black, but retain some of their dolomitic content, especially in the upper parts (Fig. 7). Their appearance, except for color, is not greatly changed, although residue fragments are normally less dolocastic than in areas to the north. Pyrite increases in abundance, and is distributed throughout the section.

Structure.—The shales thin and disappear in northern Sedgwick and northwestern Butler counties (Figs. 1 and 2). In the east the line of disappearance coincides approximately with the Nemaha arch, but no such structure is present

on the south. Somewhat similar thinning occurs in the overlying Hunton strata and also in the underlying Viola formation. Probably early Paleozoic seas left thinner deposits in southeastern Kansas than in the Salina basin on the north.

SUMMARY AND CONCLUSIONS

Muddy Upper Ordovician seas left shale deposits over much of central Kansas. These beds occupy a stratigraphic position similar to that of the Maquoketa formation in northeastern Iowa, and the Sylvan formation in Oklahoma, and are called Maquoketa-Sylvan shales, but exact correlations have not been carried across the intervening subsurface sections.

Over much of central Kansas this Maquoketa-Sylvan shale comprises two members: (1) an upper dolomitic gray shale which contains varying amounts of siliceous cherty material, and grades downward into (2) a soft gray flaky relatively non-dolomitic and non-siliceous shale. Residues, especially of the upper member, are dolocastic.

The beds are thickest in the center of the Salina basin, and in a north-south belt centering in western Harvey County. They have been removed by truncation from the Nemaha arch and the Central Kansas uplift, although probably they were never continuous over all of the latter structure. They disappear toward the southeast in Sedgwick and Butler counties, probably through a combination of truncation and non-deposition. They are thin or missing in some areas where they lie directly beneath Chattanooga shales, having been removed by pre-Chattanooga erosion.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 31, NO. 9 (SEPTEMBER, 1947), PP. 1608-1618, 3 FIGS.

MISSISSIPPIAN ROCKS OF MERAMEC AGE ALONG ALCAN HIGHWAY, NORTHERN BRITISH COLUMBIA[1]

LOWELL R. LAUDON[2] AND B. J. CHRONIC, JR.[2]
Lawrence, Kansas

ABSTRACT

Mississippian rocks are exposed at many places along the Alcan Highway in northern British Columbia from Mile 381 along the Tetsa River northwestward beyond the Liard River crossing. They consist of gray, slabby, silty limestone beds rhythmically interbedded with soft silty calcareous shales. The upper part of the section becomes thin-bedded and on weathered exposures appears as dark green chert. Maximum sections approach 350 feet in thickness. Analysis of the fauna shows the abundant occurrence of *Dictyoclostus inflatus* var. *coloradoensis*, *Spirifer arkansanus*, *Marginifera adairensis*, *Leiorhynchus carboniferum*, and *Deltopecten batesvillensis*. This fauna is early Meramec in age and can be directly correlated with some part of the Calico Bluff section in Alaska and with the Moorefield formation of the Arkansas Ozark section. No faunas of Kinderhook or Osage age occur along the Alcan Highway.

INTRODUCTION

Plans were laid in the spring of 1946 for a geologic expedition into the valley of the South Nahanni River in Yukon Territory, Canada. The purpose of this proposed expedition was to study the stratigraphy of the Paleozoic section exposed in the area and to make correlations wherever possible with the well known Paleozoic section in the Norman Wells area along the Mackenzie River. Due to special conditions brought about by the ending of the war, airplane transportation was not available at Watson Lake during the summer of 1946 until such a late date as to make a trip into the South Nahanni country very hazardous.

Since the Paleozoic sections exposed along the Alcan Highway offered the best substitute for the original plan, it was decided to make detailed studies in this area. Accordingly, detailed sections were measured and faunas collected wherever available. The structure of the area is complicated by extensive thrust faulting and folding which made the problem of measuring complete sections exceedingly difficult.

This paper covers only a small part of the work completed. Work is also in progress on description of the remarkable cyclic sedimentation that occurs throughout all Paleozoic rocks in the area.

LOCATION

The Mississippian rocks studied in connection with this paper lie along the Alcan Highway from the Liard bridge on the northwest to Mile 381 along the Tetsa River on the southeast. The exposures along the Liard River are poor and incomplete. The best section along the Liard River is on the north bank of the river beneath the new Alcan Highway Bridge at the Liard crossing. All rocks have been very much disturbed along the lower part of the Trout River valley and, although Mississippian rocks are present, no sections were studied in detail.

[1] Manuscript received, May 10, 1947.

[2] Department of geology, University of Kansas.

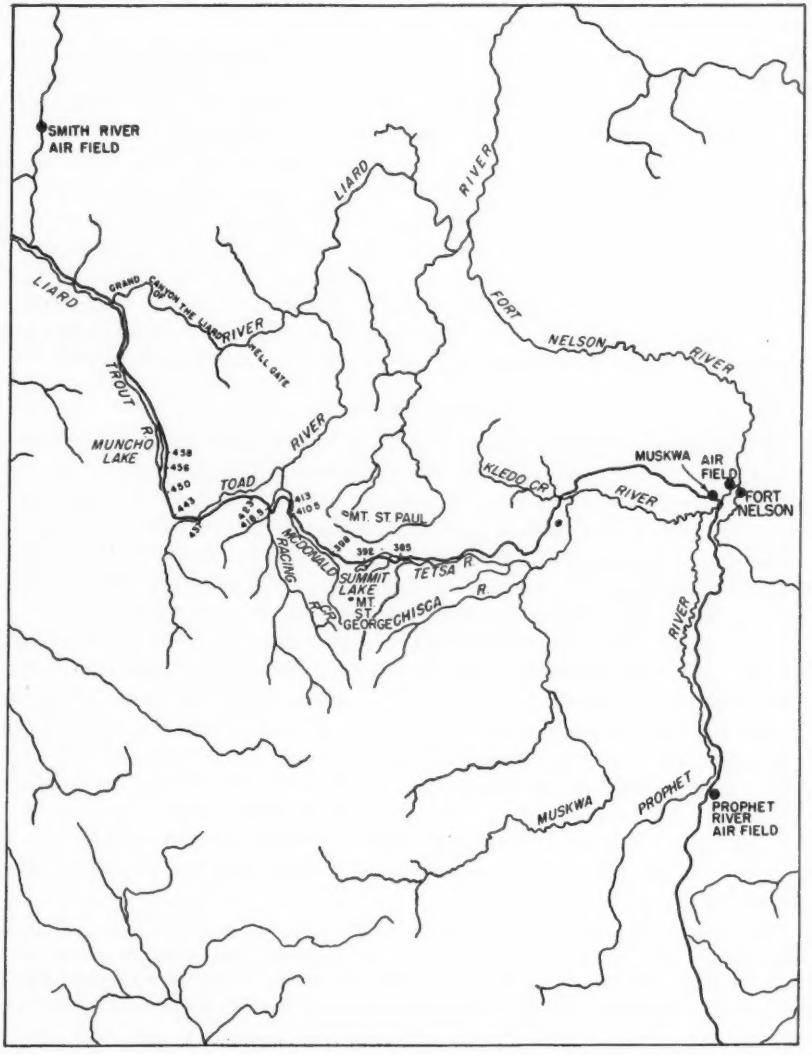


FIG. 1.—General map of Alcan Highway between Fort Nelson and Liard crossing.

Excellent sections, many complete with both contacts exposed, can be studied on either side of the Toad River from Mile 429 eastward to the Racing River bridge at Mile 418. One excellent section is fully exposed in a small valley tributary to the Toad River from the south in Mile 418. This section, which shows

remarkable cyclic sedimentation, is only a short distance south of the highway. In this area, in a succession of three valleys, upper Ramparts, Fort Creek, Mississippian, and Triassic sections are all excellently exposed. Fossiliferous Mississippian rocks are available for study above the waterfalls in a small creek valley that enters McDonald valley from the southwest in Mile 413.

Mississippian rocks are exposed along both sides of the Tetsa River from Mile 389 eastward to Mile 381. In most cases they are bush-covered and the contacts are poorly exposed. One excellent very fossiliferous section was located by Williams (1944, p. 5) in a small creek valley on the north side of the highway at Mile 381.5. The Fort Creek contact is not exposed, but projection of the contact from a near-by hillside indicates that it is close to the basal Mississippian beds exposed in this creek valley. The Triassic contact above is excellently exposed. No rocks of Mississippian age are exposed eastward from Mile 381.

PREVIOUS WORK

First information concerning the geology of the Liard River and adjacent areas is found in the scientific reports of Dawson (1888, pp. 5b–277b) in connection with his historic expedition down the Dease River, up the Frances River, down the Pelly River, and back to the coast *via* the Lewes River. This report is remarkable in its detail and accuracy. Although Dawson did not enter the area with which this paper is concerned, his description of the geology of adjacent areas corresponds closely with the geology observed along the Alcan Highway.

The geology of the Liard River valley was first described by McConnell (1891, pp. 5d–163d) who headed one part of the original Dawson exploration party. The McConnell party left the Dawson party at the mouth of the Dease River and proceeded down the Liard River. This report, like that of Dawson, is remarkable for its accuracy considering the state of stratigraphic knowledge at that time. McConnell recognized pre-Cambrian, Cambro-Silurian, Devonian, Devono-Carboniferous, Triassic, Cretaceous, and Tertiary rocks.

First recognition of Carboniferous rocks was made by McConnell (1891, p. 55d) on the Liard River 12 miles downstream from Fort Liard. The following fossils were identified.

> A *Streptorhynchus* of the type of *S. umbraculum;* two ribbed species of *Spirifera*, one of which is very like *S. centronata* Winchell; a smooth *Spirifera* of the *Martinia* section, probably identical with *S. setigera* Hall but closely related to *S. fimbriata* Conrad; *Athyris subquadrata* Hall; a new species of *Platyceras;* and *Proetus peroccidens* Hall and Whitfield.

The writers have not seen this fauna, but the general relationships make it certain that it is the same as the fauna that occurs along the Alcan Highway with which this paper is concerned. Most of the species that now characterize the Moorefield fauna of the Arkansas Ozark area had not been described at the time these identifications were made.

More extensive collections of this same fauna were made by Hume (1923, p. 49) at three localities along the Liard River about half way between Fort Liard

and the junction of the South Nahanni River. The fossils, identified by Schuchert, show a curious assemblage of Kinderhook and Osage species so exceptional as to suggest possible mis-identification. The presence of *Spirifer grimesi* and *Spirifer gregeri,* species that are practically unknown in the cordilleran province, is questionable. It is likely that *S. arkansanus* has been mistaken for these common Mississippi valley species.

A section "at least 600 feet thick" composed of limestone and shale is reported by Hume. This section is considerably thicker than any observed along the Alcan Highway, and it is entirely possible that Kinderhook beds are represented in this section.

No Mississippian rocks were noted by Cameron and Warren (1938, pp. 15–21) in their study of the geology of the South Nahanni River valley.

Williams (1944, pp. 1–33) accomplished the first detailed work with regard to Mississippian rocks. Most of the good exposures studied in connection with this report were located by Williams. In the case of the excellent, very fossiliferous exposure at Mile 381.5 in the Tetsa River valley, the location was so obscure that the writers would certainly have passed it without the detailed observations of Williams.

The general reconnaissance nature of the work of Williams did not permit, in the short time allotted to it, the details of the stratigraphy to be completed. The beds (Williams, 1944, p. 18) assigned to Kinderhook age and correlated with the Banff shale actually are well up in the Mississippian section above beds later (p. 20) referred to the Osage (Burlington and Keokuk).

The upper chert beds which are here considered as part of the Mississippian section were referred to the Permian by Williams (p. 21).

STRATIGRAPHY

Paleozoic rocks are exposed along the Alcan Highway at intervals from Mile 381 all the way across northern British Columbia and Yukon. The good exposures are mainly limited to the Rocky Mountain area from Mile 381 on as far as Watson Lake. In the area westward from Watson Lake in Yukon the highway winds through broad, glaciated, gravel-filled valleys and exposures are largely limited to mountain blocks ordinarily at a considerable distance from the road. The best exposures are in the area between Mile 381 in the Summit Lake region and the Muncho Lake-Trout River valley area. The region along the Liard River between the mouth of the Trout River and Watson Lake is low and rolling, and the exposures are relatively unspectacular.

The regional structure of the area lies in elongate slowly curving arcs that trend N. 20° W. in the Summit Lake area and N. 23° W. in the Muncho Lake area. Older Paleozoic rocks (Cambrian to Devonian) are brought to the surface in two complexly folded, faulted, parallel areas within the Rocky Mountains in this area. One of these areas is along the Summit Lake-McDonald Creek region. The other trends through the Muncho Lake area and parallels the Trout River

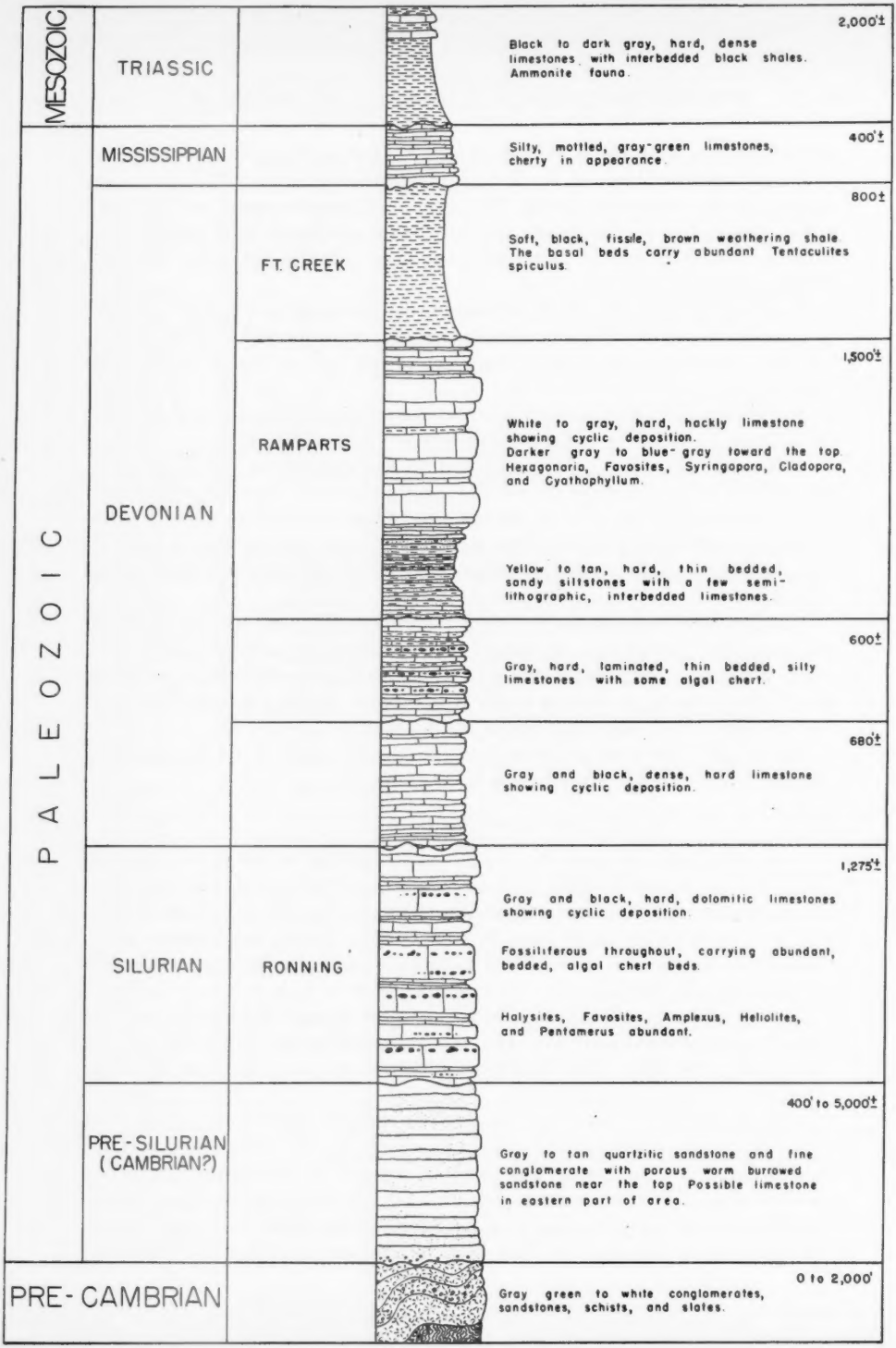

MESOZOIC
TRIASSIC
2,000'±
Black to dark gray, hard, dense limestones with interbedded black shales. Ammonite fauna.
PALEOZOIC
MISSISSIPPIAN
400'±
Silty, mottled, gray-green limestones, cherty in appearance.
DEVONIAN
FT. CREEK
800±
Soft, black, fissile, brown weathering shale. The basal beds carry abundant Tentaculites spiculus.
RAMPARTS
1,500'±
White to gray, hard, hackly limestone showing cyclic deposition. Darker gray to blue-gray toward the top. Hexagonaria, Favosites, Syringopora, Cladopora, and Cyathophyllum.
Yellow to tan, hard, thin bedded, sandy siltstones with a few semi-lithographic, interbedded limestones.
600±
Gray, hard, laminated, thin bedded, silty limestones with some algal chert.
680'±
Gray and black, dense, hard limestone showing cyclic deposition.
SILURIAN
RONNING
1,275'±
Gray and black, hard, dolomitic limestones showing cyclic deposition.
Fossiliferous throughout, carrying abundant, bedded, algal chert beds.
Halysites, Favosites, Amplexus, Heliolites, and Pentamerus abundant.
PRE-SILURIAN (CAMBRIAN?)
400' to 5,000'±
Gray to tan quartzitic sandstone and fine conglomerate with porous worm burrowed sandstone near the top. Possible limestone in eastern part of area.
PRE-CAMBRIAN
0 to 2,000'
Gray green to white conglomerates, sandstones, schists, and slates.

FIG. 2.—Composite geologic column.

valley. Younger rocks, mainly Mississippian and Triassic, lie in the downfolded area between the two areas of older Paleozoic rocks.

The Paleozoic section exposed in the area consists mainly of Silurian, Devonian, and Mississippian rocks. A variable section of slightly folded limestone and sandstone beds lies unconformably beneath Silurian rocks over most of the area. It was definitely folded before the Silurian rocks were deposited, and the folds were truncated by pre-Silurian erosion. These limestone and sandstone beds appear to overlie the pre-Cambrian schists, quartzites, slates, and marbles unconformably. No fossils have been found in them so their age can not be determined at present.

In the Muncho Lake area flat tan sandstone and quartzite beds overlie pre-Cambrian schists and phyllites unconformably. These sand beds are not discordant with the overlying Silurian although the contact is distinctly unconformable. Lithologically they closely resemble the sands of the MacDougal group of Cambrian age in the Mackenzie Mountains (Hume and Link, 1945, p. 9).

The Silurian system is represented by one formation, the Ronning, of Niagaran age. It consists of slightly more than 1,200 feet of cyclic dolomitic limestone beds that contain abundant algal chert and fossil corals. The entire section, excepting the base, consists of a series of thin-bedded, black, shaly, very fossiliferous limestone beds rhythmically alternating with more massive, gray, non-fossiliferous, dolomitic limestone beds.

The Devonian system is represented by five formations, the exact stratigraphic relations of which are not known as yet. The basal unit consists of 680 feet of cyclic gray and black non-fossiliferous limestone. The second unit consists of approximately 600 feet of cyclic gray and black limestone very similar to the basal unit. It is separated from the basal unit by a minor unconformity and by a marked break-down of cyclic sedimentation on either side of the unconformity. No diagnostic fossils were found. The third unit consists of rhythmically cyclic sandstone and sandy limestone beds that appear to grade imperceptibly up into the overlying Ramparts limestone. These sandy beds form a tan-yellow cliff easily recognizable throughout the area. The Ramparts formation consists of more than 1,000 feet of rhythmically cyclic limestone beds. The basal part is light gray in color and the upper part is darker. Typical Ramparts fossils occur in the upper part of the section. The Ramparts is unconformably overlain by the Fort Creek shale. The Fort Creek consists of approximately 800 feet of thin-bedded, black, laminated, pyritic shale that weathers yellow-brown. *Tentaculites* occurs abundantly in the basal beds as it does in the Norman Wells area at the type section of the Fort Creek.

Mississippian rocks rest unconformably on the Fort Creek formation. No rocks of Pennsylvanian and Permian age occur in the area.

The Mississippian rocks are lithologically uniform and distinctive throughout the area. They are easily recognized because they differ markedly from all other formations. There is a slight lithologic change from the base upward in the sec-

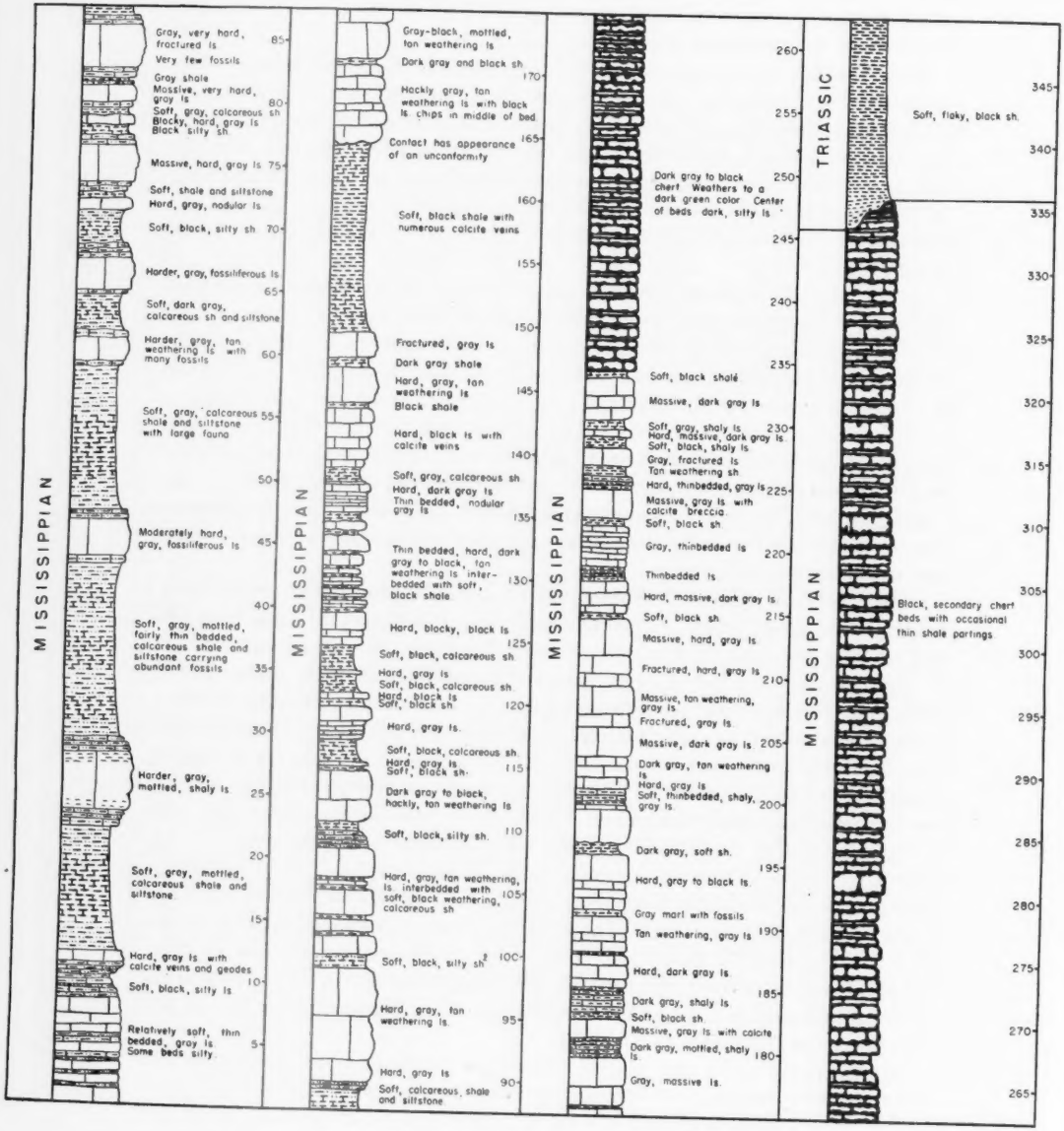

MISSISSIPPIAN
Gray, very hard, fractured ls
Very few fossils
Gray shale
Massive, very hard, gray ls
Soft, gray, calcareous sh
Blocky, hard, gray ls
Black silty sh
Massive, hard, gray ls
Soft, shale and siltstone
Hard, gray, nodular ls
Soft, black, silty sh
Harder, gray, fossiliferous ls
Soft, dark gray, calcareous sh and siltstone
Harder, gray, tan weathering ls with many fossils
Soft, gray, calcareous shale and siltstone with large fauna
Moderately hard, gray, fossiliferous ls
Soft, gray, mottled, fairly thin bedded, calcareous shale and siltstone carrying abundant fossils
Harder, gray, mottled, shaly ls
Soft, gray, mottled, calcareous shale and siltstone
Hard, gray ls with calcite veins and geodes
Soft, black, silty ls
Relatively soft, thin bedded, gray ls Some beds silty
MISSISSIPPIAN
Gray-black, mottled, tan weathering ls
Dark gray and black sh
Hackly gray, tan weathering ls with black ls chips in middle of bed
Contact has appearance of an unconformity
Soft, black shale with numerous calcite veins
Fractured, gray ls
Dark gray shale
Hard, gray, tan weathering ls
Black shale
Hard, black ls with calcite veins
Soft, gray, calcareous sh
Hard, dark gray ls
Thin bedded, nodular gray ls
Thin bedded, hard, dark gray to black, tan weathering ls interbedded with soft, black shale
Hard, blocky, black ls
Soft, black, calcareous sh
Hard, gray ls
Soft, black, calcareous sh
Hard, black ls
Soft, black sh
Hard, gray ls
Soft, black, calcareous sh
Hard, gray ls
Soft, black sh
Dark gray to black, hackly, tan weathering ls
Soft, black, silty sh
Hard, gray, tan weathering, ls interbedded with soft, black weathering, calcareous sh
Soft, black, silty sh?
Hard, gray, tan weathering ls
Hard, gray ls
Soft, calcareous shale and siltstone
MISSISSIPPIAN
Dark gray to black chert Weathers to a dark green color Center of beds dark, silty ls
Soft, black shale
Massive, dark gray ls
Soft, gray, shaly ls
Hard, massive, dark gray ls
Soft, black, shaly ls
Gray, fractured ls Tan weathering sh
Hard, thinbedded, gray ls
Massive, gray ls with calcite breccia
Soft, black sh
Gray, thinbedded ls
Thinbedded ls
Hard, massive, dark gray ls
Soft, black sh
Massive, hard, gray ls
Fractured, hard, gray ls
Massive, tan weathering, gray ls
Fractured, gray ls
Massive, dark gray ls
Dark gray, tan weathering ls
Hard, gray ls
Soft, thinbedded, shaly, gray ls
Dark gray, soft sh
Hard, gray to black ls
Gray marl with fossils
Tan weathering, gray ls
Hard, dark gray ls
Dark gray, shaly ls
Soft, black sh
Massive, gray ls with calcite
Dark gray, mottled, shaly ls
Gray, massive ls
TRIASSIC
MISSISSIPPIAN
Soft, flaky, black sh
Black, secondary chert beds with occasional thin shale partings

FIG. 3.—Mississippian section, north bluff of Tetsa River, Mile 381.5.

tion, but it is gradual. In the central part of the section there is some evidence of unconformity that may justify division into two formations.

The writers are not proposing names for the rocks of this area at present because of the reconnaissance nature of the work. As geographic names in the area are almost non-existent, assignment of appropriate formational names would demand naming geographic features. It is deemed best to wait for a comprehensive survey of the area.

The basal part of the section consists of massive, gray, silty, limestone beds that flake off parallel with the bedding planes in large flat chips. These basal beds are very silty and contain only 13.4 per cent calcium carbonate. Each massive bed grades imperceptibly up and down into soft, thin-bedded, silty, gray to black, shale beds. Both shales and limestone beds are prolifically fossiliferous. The percentage of massive limestone to shale gradually increases upward. In the central part of the section they occur in about equal amounts. One conspicuous shale bed approximately 15 feet in thickness occurs near the middle of the section. In the Tetsa River section in Mile 381.5 this shale bed is 150 feet above the base. Such a thickness is of little value however, since Mississippian rocks were deposited on a surface that had marked relief.

The contact between this shale bed and the overlying limestone has some of the characteristics of an unconformable surface. The contact appears to be slightly irregular, the lithologic change is abrupt, and thin local conglomerate beds are developed in the basal beds of the limestone.

The limestone beds immediately above this contact form a conspicuous escarpment. They consist of hard, irregularly bedded, gray to light tan, sandy limestone beds that are filled with calcite veins. The scarp-forming sequence is about 8 feet in thickness. If a hiatus is present between the shale and limestone beds, it is of short time duration because the overlying beds are very similar lithologically to the basal beds. The fossils also show close relationships to the fauna in the basal beds.

The upper part of the section consists of a rhythmically alternating series of gray, silty limestone beds and darker, green to black, mottled, sandy shale beds. The percentage of shale decreases and the percentage of limestone increases toward the top. The upper 100 feet consists almost entirely of thin-bedded, gray, silty limestone with thin shale partings. On weathered exposures this upper part has been partly altered so that it commonly appears as a dark green to black, chert escarpment.

On fresh exposures such as the section observed along the south side of the Toad River in Mile 418, the central part of the section consists of strikingly rhythmic alternations of massive, rust-brown weathering, sandy limestone beds with strange, peculiarly mottled, dark green, sandy shale beds. The strange, mottled, green, sandy shale beds are repeated so consistently as to make the cyclic nature immediately obvious.

Mississippian rocks are overlain by Triassic rocks with marked unconformity.

The lithologic change is abrupt; a red oxidized zone commonly marks the contact, and local silicious conglomerate beds lie in the base of the Triassic.

PALEONTOLOGY AND CORRELATION

Fossils occur abundantly in the lower part of the Mississippian rocks and with moderate abundance in the central part of the section. The upper cherty beds, however, are devoid of recognizable fossils. The fauna that occurs near the basal part of the section is slightly different from the fauna that occurs in the beds in the central part above the possible unconformity. Some species cross the line and it is probable that if an unconformity is present the time interval represented is not great.

The most fossiliferous outcrop of Mississippian rocks was located by Williams (1944, p. 20) in a small creek valley a short distance north of the highway at Mile 381.5 in the Tetsa River valley. These beds are near the base of the section. The following fauna has been identified: *Productina* sp., *Productella* sp., *Productella* sp., *Productella moorefieldana*, *Avonia oklahomaensis*, *Dictyoclostus inflatus* var. *coloradoensis*, *Dictyoclostus* sp., *Linoproductus pileiformis*, *Linoproductus altonensis*, *Marginifera adairensis*, *Buxtonia* sp., *Leiorhynchus carboniferum*, *Spirifer arkansanus*, *Brachythyris gurleyi*, *Ambocoelia* sp., and *Deltopecten batesvillensis*.

Most of the fossils listed occur in the Calico Bluff formation (Mertie, 1937, p. 133) on the Yukon River at Eagle in Alaska. The fauna of the Calico Bluff formation is of early Meramec age and lies under the Lisburne limestone (Smith and Mertie, 1930, p. 182). The Lisburne limestone contains a fauna of middle Meramec age most closely referable to that of the St. Louis limestone of the Mississippi Valley area.

Productella moorefieldana, *Dictyoclostus inflatus* var. *coloradoensis*, *Leiorhynchus carboniferum*, *Spirifer arkansanus*, and *Deltopecten batesvillensis* are the abundant commonly occurring forms in the Moorefield formation of the Ozark area (Girty, 1911, p. 22). They are all distinctive in character so that there is little chance for mis-identification. They are also practically restricted to the Moorefield formation and its equivalents.

The Moorefield formation rests on the sharply truncated surface of the Osage series in the Mississippi valley area. In the Batesville area a karst topography is developed on the Osage surface and practically every bed of the Moorefield and Batesville section can be seen in contact with the underlying Osage rocks in some part of the area. In northeastern Oklahoma both Cline (1934, p. 1157) and Laudon (1939, p. 338) have demonstrated that the Mayes (Moorefield) formation overlaps the Osage section with marked unconformity. Lee (1940, p. 77) has demonstrated that the Cowley formation, a correlative of the Moorefield, rests on a markedly unconformable Osage surface throughout the subsurface of Kansas. Laudon and Bowsher (1942, p. 29) have shown that the lower part of the Helms formation contains a fauna of Moorefield age and that it overlaps the Osage section in the southern part of the Sacramento Mountains and San Andres Mountains in New Mexico.

The beds of the Calico Bluff formation in Alaska and the Moorefield equivalents in the Mid-Continent area represent the earliest sedimentation after the long erosion period at the end of the Osage epoch. The dramatic extinction of the great Osage crinoid and brachiopod faunas is ample evidence of the magnitude of this unconformity.

A few fossils occur in limestone beds near the middle of the section, beneath the green chert limestone beds and above the possible unconformity. Fossils from this zone were collected beneath the Liard bridge, above a small waterfall on the west side of McDonald Creek at Mile 413, and in the middle part of the same section that produced the excellent fauna at Mile 381.5 along the Tetsa River.

The following fossils have been identified from these beds: *Orbiculoidea batesvillensis, Rhynchopora rowleyi, Leiorhynchus* sp., *Martinopsis* sp., *Spirifer arkansanus, Spirifer moorefieldana, Spirifer* sp., *Brachythyris gurleyi, Ambocoelia* sp., and *Deltopecten batesvillensis*. The common fossils in this fauna occur also in the lower beds indicating that, if an unconformity is present, it is not of great time duration. The almost complete absence of productid brachiopods in the upper fauna makes it immediately distinguishable from the lower fauna. In some parts of this section along Tetsa River the rock is made up almost entirely of excellent specimens of a large species of *Martinopsis*.

No beds of Kinderhook age occur in this area. The thick Kinderhook rocks of the Banff area (Shimer, 1926, p. 7) and the Jasper Park area (Kindle, 1929, p. 189) are entirely missing. The Rundle limestone of the Banff and Jasper Park areas rests with sharp unconformity on Kinderhook beds, and no Osage rocks are present in these areas. The fauna of the Rundle limestone is of middle Meramec age and probably correlates most closely with the Lisburne limestone of Alaska. The abundant occurrence of *Lithostrotion* in the fauna and the distinctive St. Louis type of lithology suggests correlation of the Rundle limestone with the St. Louis limestone of the Mississippi valley area. The stratigraphic position of the Mississippian beds that occur along the Alcan Highway in northern British Columbia is between the Kinderhook strata and the Rundle limestone.

BIBLIOGRAPHY

1. CAMERON, A. E., AND WARREN, P. S. (1938), "Geology of South Nahanni River, N. W. T.," *Canadian Field Naturalist*, Vol. 52, No. 2 (February), pp. 15–21.
2. CLINE, L. M. (1934), "Osage Formations of Southern Ozark Region, Missouri, Arkansas, and Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 9 (September, 1934), pp. 1132–59.
3. DAWSON, G. M. (1888), "Report on an Exploration in Yukon District, Northwest Territories, and Adjacent Northern Portion of British Columbia," *Geol. and Nat. Hist. Survey of Canada, Ann. Rept.* (New Ser.), Vol. 3, Pt. 1, Rept. B, pp. 31–46.
4. GIRTY, GEORGE H. (1911), "The Fauna of the Moorefield Shale of Arkansas," *U. S. Geol. Survey Bull. 439*. 148 pp., 15 pls.
5. HUME, G. S. (1923), "A Kinderhook Fauna from the Liard River, N. W. T., Canada," *Amer. Jour. Sci.*, Ser. 5, Vol. 6, No. 31, Art. 6 (July), pp. 48–52.
6. HUME, G. S., AND LINK, T. A. (1945), "Canol Geological Investigations in the Mackenzie River Area, Northwest Territories and Yukon," *Canada Dept. Mines and Res., Mines and Geol. Br., Geol. Survey, Paper 45–16*.
7. KINDLE, E. M. (1929), "The Succession of Fossil Faunas in the Eastern Part of Jasper Park," *Amer. Jour. Sci.*, Ser. 5, Vol. 18, No. 105 (September), pp. 177–92.
8. LAUDON, L. R. (1930), "Stratigraphy of Osage Subseries of Northeastern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 3 (March), pp. 325–38; 13 figs.

9. LAUDON, L. R., AND BOWSHER, A. L. (1941), "Mississippian Formations of Sacramento Mountains, New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, No. 12 (December), pp. 2107–60; 31 figs.
10. LEE, WALLACE (1940), "Subsurface Mississippian Rocks of Kansas," *Kansas Geol. Survey Bull. 33.*
11. MCCONNELL, R. G. (1891), "Report on an Exploration in the Yukon and Mackenzie Basins," *Geol. and Nat. Hist. Survey of Canada, Ann. Rept.* (New Ser.), Vol. 4 (1888–1889), Rept. D, pp. 1–145.
12. MERTIE, J. B., JR. (1937), "The Yukon-Tanana Region, Alaska," *U. S. Geol. Survey Bull. 872.* 276 pp., 15 pls.
13. SHIMER, H. W. (1926), "Upper Paleozoic Faunas of the Lake Minnewanka Section, Near Banff, Alberta," *Canada Dept. of Mines, Geol. Survey, Bull. 42*, Geol. Ser., No. 45 (May 8), pp. 1–84, Pls. 1–8.
14. SMITH, PHILIP S., AND MERTIE, J. B., JR. (1930), "Geology and Mineral Resources of Northwestern Alaska," *U. S. Geol. Survey Bull. 815.* 351 pp., 34 pls., 22 figs.
15. WILLIAMS, M. Y. (1944), "Geological Reconnaissance along the Alaska Highway from Fort Nelson, British Columbia, to Watson Lake, Yukon," *Canada Dept. of Mines and Res., Mines and Geol. Br., Geol. Survey, Paper 45–28*, pp.1–33.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 31, NO. 9 (SEPTEMBER, 1947), PP. 1619-1663, 7 FIGS.

EQUILIBRIUM OF FORM AND FORCES IN TIDAL BASINS OF COAST OF TEXAS AND LOUISIANA[1]

W. ARMSTRONG PRICE[2]
Corpus Christi, Texas

ABSTRACT

Study of 31 oval, enclosed tidal basins of a variety of sizes in soft sediments shows approximate dynamic equilibrium, regardless of basin origin, between average width and maximum depth, scour and fill, fetch (width) and wave base to the maximum observed depth of 16.5 feet. On the humid eastern coast, basins are commonly wide, shallow and directly alluviated by rivers. Equation of straight line average where y=depth in feet, and x=width in miles, is $y=0.41x+3.0$. On the non-humid southwestern coast, basins are proportionately narrower; straight line average is $y=x$, or a ratio of 1:1. Here, most elongate water bodies have become segmented to oval form by spits, bars, tidal deltas, and washover fans. Alluviation commonly overcomes disposal in inner segments entered by rivers, filling them while leaving outer segments in equilibrium. Depths in tidal channels are not used. Water bodies for which data are incomplete, those with very irregular outlines, and unsegmented parts of coastal lagoons are excluded.

With two exceptions, maximum departure from average depth during the record period has been 2–3 feet, 30 per cent, essentially within the range of incidental scour and fill and secular sea-level change. A shallowing of most basins since early surveys by 0.5–1.5 feet is believed to show mainly silting due to man's activities. Heavier silting and segmentation are caused by ship-channel excavation across basins. Segmentation, artificial or natural, tends to restore equilibrium, following or being followed by bottom filling. Modification of form is most evident after great storms or major engineering works.

In spite of postulated eustatic sea-level rise during the present century, the tidal basins have maintained width-depth ratios, in some cases actual depths, during equilibrium conditions in the cartographic period. Some bays sank 10+ feet in recent centuries but now have equilibrium of form.

Sedimentation in the basins is briefly studied in relation to the laws here investigated, to basin origin, and to its effect on bottom-dwelling organisms, chiefly the oyster.

The washover fan, a minor topographic and sedimentary feature of the lagoon side of offshore bars, has not been described before in the geologic literature of Texas.

INTRODUCTION

Objects of study.—From examination of the Coast Charts, the writer noted some years ago (Price, 1933b, pp. 931–33, Figs. 2, 7) that there seemed to be a relationship between width and depth in the larger, more or less enclosed and oval to round bodies of tidewater in Texas and that the same relationship held in similar small basins not being directly invaded by growing bay-head deltas. A later sampling of similar basins from the Charts for Louisiana showed essentially the same conditions. This relationship was seen to be essentially a constancy in the ratio of width to depth regardless of basin size. It seemed to show that there was an equilibrium of forces in the basins.

The present study is the writer's second attempt to determine the degree of constancy of ratio existing and the limits within which an equilibrium of forces might apply. The implications of the existence of such an equilibrium are here inquired into.[3] In order to accomplish these aims, it is necessary to review some-

[1] Manuscript received, December 4, 1946.

[2] Consulting geologist.

[3] Dynamic equilibrium among numerous variables of physical and chemical hydrology, with sug-

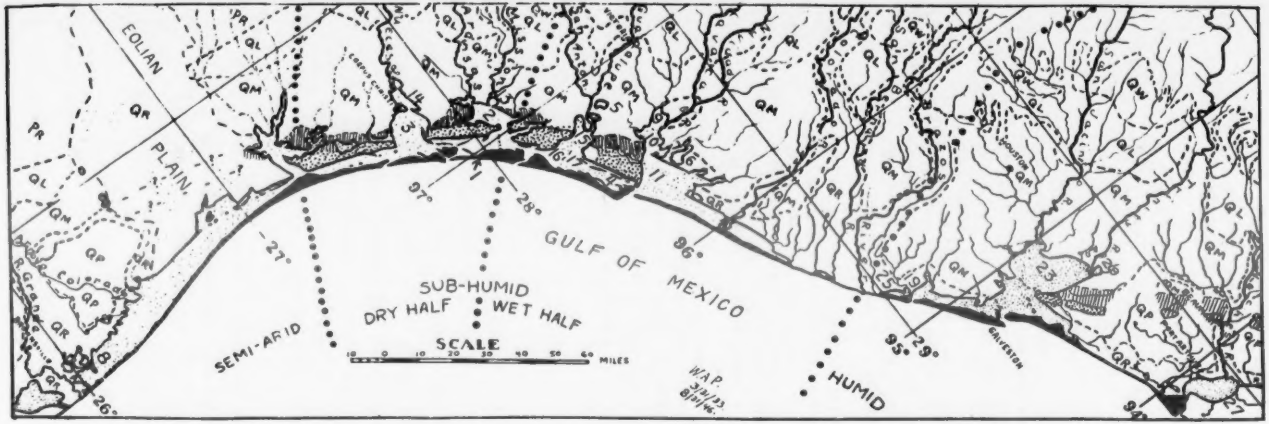
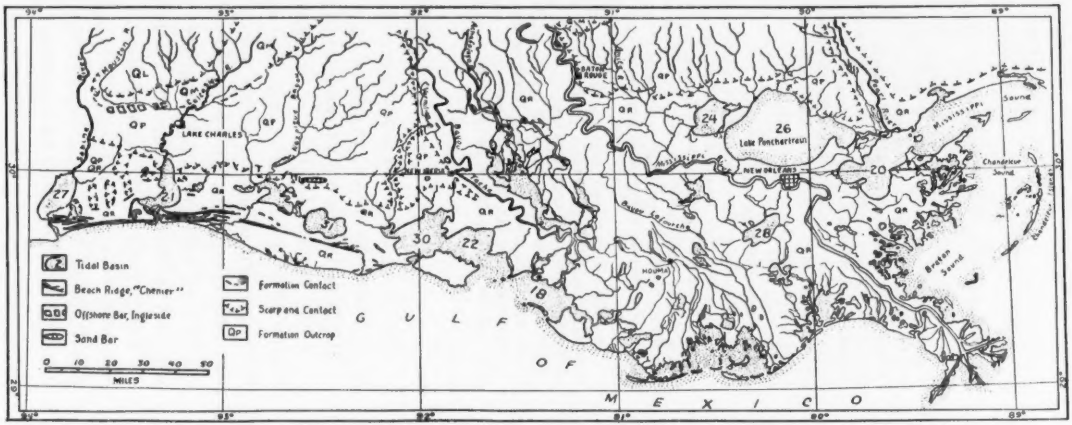


FIG. 1.—Location map, showing Quaternary geologic formation outcrops. Numbers refer to basins of Figure 5 and Table I.

1a. TEXAS. Offshore bar, islands, and reefs, black. Pleistocene Ingleside offshore bar, heavy stipple. Drained Ingleside lagoon areas, diagonal-line pattern. Probable course of Ingleside terrace under eolian cover, broken lines. QW, Willis; QL, Lissie; QM, older, or Montgomery, Beaumont; QP, younger, or Prairie, Beaumont. Climatic zonation after Thornthwaite.



1b. LOUISIANA. See legend on illustration. Formations as in 1a.

what briefly the late geologic history of the region and the limitations of the data used.

It has not been a part of this investigation to make a detailed study of sedimentation, in the field or from compiled data, but it is profitable to discuss some aspects of the subject in general terms.

Tidewater basins.—The tidewater region of the Gulf of Mexico from the Mississippi delta to the Rio Grande delta is the site of numerous shallow, more or less flat-bottomed lagoons, bays, and lakes (Fig. 1) lying in unconsolidated sands and clays. Most of these are what we here term, "enclosed," although they are connected with the Gulf more or less indirectly through inlets in the offshore bars and other long or short tidal channels, some of which are locally 2 or 3 times as deep as the associated bays and lagoons. To-day, the intracoastal canal and, especially in Louisiana, many branch canals connect most of the inland lakes of the coastal group with tidewater. The inlets through the offshore bar are, in several cases,[4] maintained for navigation by dredging. Dredged deep-water ship channels connect the major ports with the Gulf.

The tidal water bodies of the region consist of (1) long, relatively narrow, enclosed segments of the coastal lagoon in which length is more than 3 or 4 times the width, (2) wider segments of these forming open-ended sounds, (3) bodies of irregular form, such as those with intricately indented inner margins formed by the numerous distributary ridges and natural levees of an abandoned and drowned delta area, and (4) enclosed basins of more or less oval shape in which most shorelines are curving and in which the longest diameter is not more than about 3 times the greatest diameter measured roughly at right angles to the first. Round and equidimensional basins occur, but are few in number. In the fourth class, just described, the water body is basin-shaped; in some, marine planation of high mainland banks, bluffed through long stretches, has occurred, and there has been some development of beaches. In most basins of this class, except in the largest of Louisiana, there is also much development of spits, bars, and oyster reefs. This class includes (a) enclosed segments of the coastal lagoon, (b) embayments of drowned valleys, (c) segments of these separated by bars and spits, (d) unfilled parts of alluvial valley plains, and (e) embayed sunken areas of deltas.

A number of characteristics of these tidal basins seem worthy of analysis. The embayed parts of a drowned river valley here typically consist of a series of more or less rounded to oval segments each having its own depth. These segments are progressively wider and deeper gulfward, but all essentially flat-bottomed, so that the present bottom of the valley descends step-wise like a flight of stairs.

---

gestions that it may occur also in marine populations, is recognized as a long-term-average condition of unit bodies of water such as the European Mediterranean by Sverdrup, Johnson, and Fleming (1942, pp. 160–63).

[4] Brazos Santiago, Aransas Pass, Bolivar Channel and Sabine Pass.

1b. LOUISIANA. See legend on illustration. Formations as in 1a.

Inner segments of these valleys act as settling basins for alluvium, while outer segments remain relatively stable in form.

An early study indicated (Price, 1933b, Figs. 2, 7; pp. 931, 932), as has been said, that there was some sort of constancy of ratio between width and depth among basins of a considerable range in size and that some of the laws of coastal processes might be learned by statistical analysis of basin forms. This seemed especially likely since constancy of ratio occurred in basins of different origins—embayed valley segments, segments of the coastal lagoon, and basins of a delta.

Those basins of tidal Texas least affected by engineering operations seem to have, in recent decades, been the most stable, but all, or nearly all, have shallowed slightly since the colonization of the coast by Anglo-American whites.

The bases of selection of basins for investigation and of basin dimensions for analysis in the early study were found, on closer inspection, not to have been the most satisfactory and some deductions resulting from it—such as the recognition of developmental stages in an "age" sequence—to be set aside by the present study.

Basins selected for study.—The writer has selected the class of enclosed tidal water bodies with more or less oval to rounded shapes as suitable for an analysis of their form. These are saucer-shaped, with gently sloping sides and relatively flat or very broadly trough-shaped bottoms. The ratio of longest diameter to greatest short diameter does not exceed about 3.25 to 1 and the ratio of maximum length in miles to maximum depth in feet does not exceed about 2.8 to 1. They are shown in Figure 1 by numbers which refer to Table I.

The tidal basins suitable for study at this time have been reduced in number by the lack of soundings for some inland basins which have very shallow waters or are otherwise economically unimportant. At this writing, there was not available a complete set of charts of the more inland waters of Louisiana. The ten included from that state should be fairly representative of the type studied.

The basins omitted include, in Texas, a number in the Rio Grande delta and some lakes of the alluvial valleys and floodplains of the rivers for which soundings have not been made. These include some basins now nearly filled with alluvium, as the inner segmented end of Nueces Bay. Elongate, trough-shaped depressions of the coastal lagoon not falling within the category of "basin" are omitted.

Cartography, and hydrographic data used.—Nautical charts of the coast of Louisiana and Texas consist of the official charts of the United States Coast and Geodetic Survey[5] and of scattered charts made by early military and naval expeditions and by pioneer commercial ship captains. While a few data are here obtained from unofficial sources, the study is based primarily on the shoreline mapping and soundings of the official surveys.

The earliest detailed hydrographic surveys of the inner basins of this coast

[5] Also maps of Corps of Engineers, United States Army, and Hydrographic Office, United States Navy.

covering entire bays[5] date from the period of 1848–1858. Additional large areas were covered in 1867–1871 and some in 1875 and 1882–1889. Surveying of shorelines from aerial photographs checked by ground surveys was begun after 1927. Large areas in this region were so surveyed in 1934 and 1935, with extensive new hydrographic surveys of the under-water areas.

Detailed studies of changes in basin outlines and depths of water would make use of unpublished prints of original surveys available from the Coast and Geodetic Survey[7] and of mean sea-level data; but, for present purposes, the published Coast Charts, without mean sea-level data, are believed to be sufficiently detailed and accurate. The Charts give selected characteristic soundings and are published at relatively frequent intervals or as often as new data in sufficient amount have accumulated. These data are obtained by Coast and Geodetic surveys, from other official surveys, and from reliable private sources.

Soundings on the Coast Charts are given in vertical distances below "mean low water." This datum is determined individually at selected places where tides are accurately observed over varying periods of time. The locations for tidal observation are selected to determine a correct low-water datum for each body of water where the range in the tides is different from adjacent waters. Although the elevations of bench-marks on land set by official surveys are in terms of "mean sea-level" of the "North American Datum," or of some datum referable to it, in only a few places are the mean low-water data determined from anything but local tidal observations. The vertical difference between mean sea-level and mean low water must be determined for each individual body of water. For the purposes of this study it has not been necessary to refer soundings to mean sea-level, or to determine to what extent the data for such conversion are available in official records. What history of the small corrections of the mean low-water datums for the several bays made in previous years may affect the successive chart editions is not known to this writer. Unless some factor operated to make these corrections trend in the same direction, such changes should average approximately zero if all the bays of the coast are considered.

Upon inquiry of the Coast and Geodetic Survey the following information was obtained relative to changes in mean low-water datums.[8]

Due to the small range of tide along the Gulf shoreline of Texas, changes in tide in the inner waters resulting from changes in the positions of inlets—the best known cause of change in tidal regime—would necessarily be small, and probably well under 0.5 foot. The greatest changes are close to the inlets. The historical changes in depths in the inner waters due to changed tide conditions are probably not greater than a few tenths of a foot in any instance.

The accuracy with which non-official soundings represent mean low water

[6] U. S. Coast and Geodetic Survey, Hydrographic Indices 87–91.

[7] Also maps of Corps of Engineers, United States Army, and Hydrographic Office, United States Navy.

[8] Letter of acting director, J. H. Hawley, August 28, 1946.

must be judged from the length of the tidal observation period as well as the reliability of the surveyors. A single trip of a ship into a bay would probably give soundings not referable to a mean, even throughout the length of the traverses made. A military or naval expedition which spent a week or more in the same body of water might obtain somewhat more accurate and comparable soundings. Where the dates and hours of soundings are known, on this coast, something may be assumed as to the possible condition of wind tides and, for recent decades, of the stage of the gravitational tides.

For the major purpose of this study, the determination of the ratios between width and depth, great accuracy in measurements is not significant. Evidences of incidental scour and fill of basin bottoms and the range of departures of width-depth ratios from the straight line equations suggest that variations from accuracy in soundings of 1 foot, or possibly 1.5 feet, plus or minus, are not significant for the major purposes of this study. Representative widths, due to shoreline and bottom irregularities, are not significant for our purposes within fractions of a mile less, possibly, than 0.25, although measurements are made to 0.1 in Table I. However, in the study of sedimentation, depth variations of a few tenths of a foot would be highly significant where they were known to represent bottom filling, not merely changes in tide regime.

H. A. Marmer (1946, p. 684) has shown that sea-level, as determined from tidal records, seems subject to relatively large secular changes. From about 1896 to 1940 the record for the Atlantic Coast of North America shows a steady rise of sea-level from 0.25 to 0.45 foot (Marmer, 1946, Fig. 3) with some local oscillation. If monthly and yearly values of sea-level position are platted, oscillations within the year and within the decade are found. Within the year, variations as great as 1.0 foot ($\pm$0.5 ft.) are found, and within the decade variations in yearly averages are as high as 0.25 foot (Marmer, 1946, Figs. 1 and 2).

The long-period sea-level change is supposed to be in part eustatic, hence complex in origin. The local change, determined by long-period averages, is considered wholly diastrophic. Factors which are known to affect short-period change, according to Marmer (1946, pp. 682–83) include: tides, waves, currents, atmospheric pressure, temperature, and density of the water, and—near the land—rainfall and run-off.

Marmer (1946, p. 684) now advocates the adoption of the record of a definite number of years and a stated epoch when defining the sea-level datum. The period now used by the Coast and Geodetic Survey is 19 years and the epoch 1924–1942.

For the purposes of the investigation of the equilibrium of width to depth in tidal basins, the short-term variations in sea-level are within what has been termed in this study the range of incidental scour and fill. It becomes one of the minor sources of error affecting the range of accuracy of the study and does not seem to alter the figure of $\pm$1.5 feet for this range.

Historians have preserved for us two charts of Matagorda and Lavaca bays

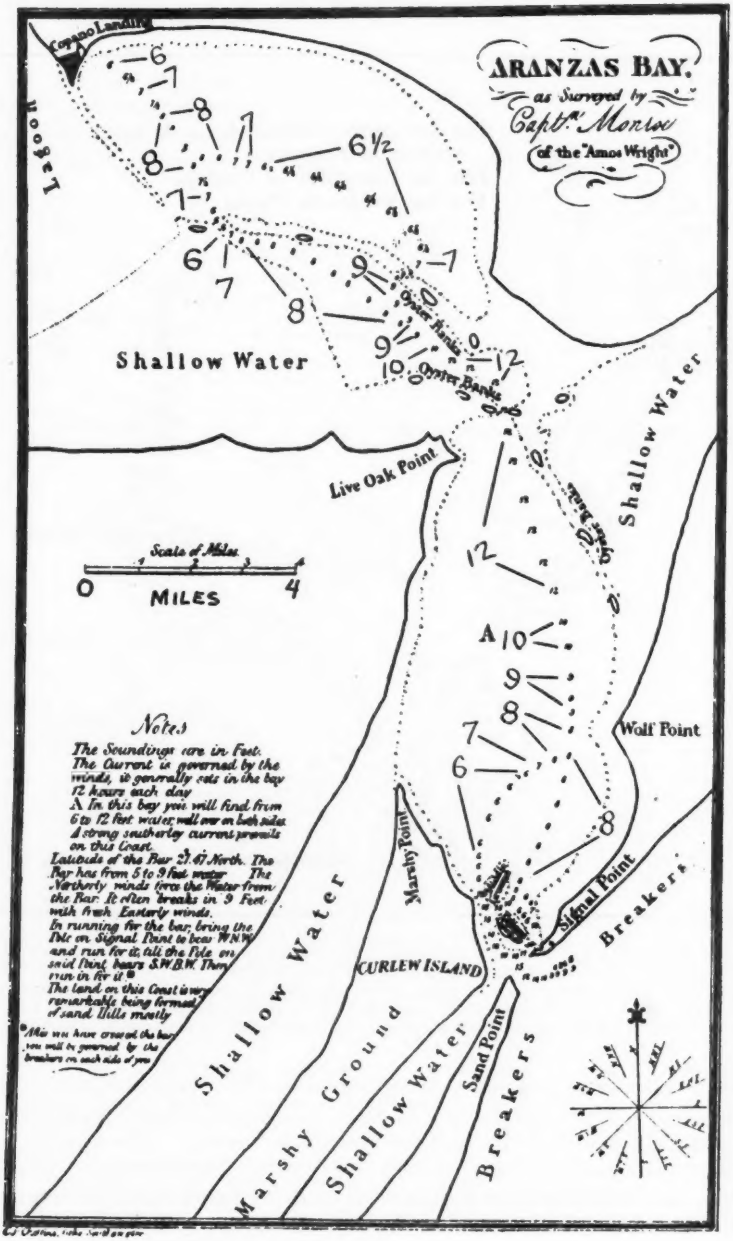
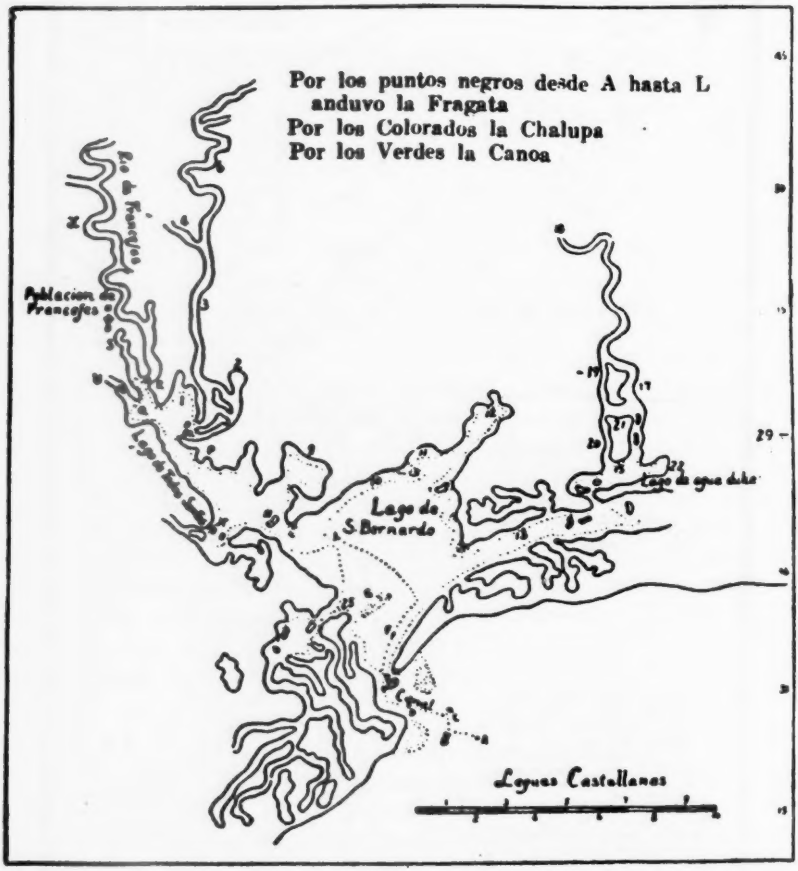

ARANZAS BAY,
as Surveyed by
Capt.n Monroe
of the "Amos Wright"
Copano Landing
Lagoon
Shallow Water
Oyster Banks
Live Oak Point
Shallow Water
Scale of Miles
0 MILES 4
Notes
The Soundings are in Feet.
The Current is governed by the winds, it generally sets in the bay 12 hours each day
A In this bay you will find from 6 to 12 feet water; all over on both sides
d strong southerly current prevails on this Coast.
Latitude of the Bar 27° 47' North. The Bar has from 5 to 9 feet water. The Northerly winds force the Water from the Bar It often breaks in 9 Feet with fresh Easterly winds.
In running for the bar, bring the Pole on Signal Point to bear W.N.W. and run for it, till the Pole on said Point, bears S.W.B.W. Then run in for it
The land on this Coast is very remarkable being formed of sand Hills mostly
Wolf Point
Marshy Point
Signal Point
Breakers
CURLEW ISLAND
Shallow Water
Marshy Ground
Shallow Water
Sand Point
Breakers

FIG. 2.—Charts of Texas basins from colonial period.

2a.—Aransas and Copano bays, 1833. By Captain Monroe of merchant ship *Amos Wright*, from Huson (1935) "El Copano," as reproduced from Kennedy's "Texas" (1841). Values for scale of miles and representative soundings added in large figures. Inner basin is Copano Bay, eastern end.

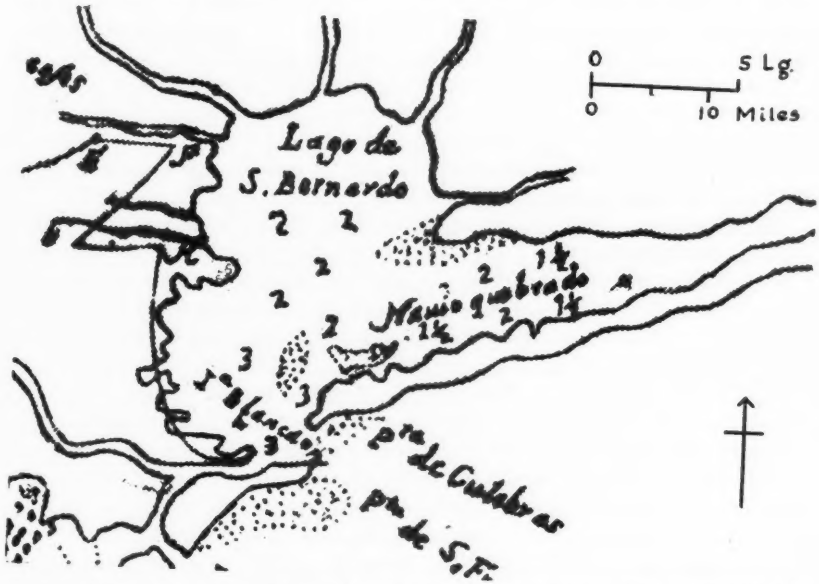

Por los puntos negros desde A hasta L
anduvo la Fragata
Por los Colorados la Chalupa
Por los Verdes la Canoa
Rio de Franceses
Poblacion de Franceses
Lago de S. Bernardo
Leguas Castellanas

2b.—Matagorda (San Bernardo) Bay in 1690. Cardenas map as redrawn by Bolton (1924) from photograph. Lago de Todos Santos is Lavaca Bay; Rio de Franceses, Garcitas Creek. Numerals and letters in water areas are traverse localities, for which no soundings are given in English commentaries. Localities 2, 3, 4 on Lavaca River; 6 on Navidad; 12 on Trespalacios; 15 to 18 on Colorado on which a "raft" of logs obstructed west channel near 19. Lavaca bay is proportionately too narrow.

made by Spanish engineers in 1689 and 1690 which have been available for study (Fig. 2, b, c). The Cardenas map (Bolton, 1915; 1924) gives no soundings, but deliniates the shorelines recognizably and with, for our purposes, only unimportant distortion. The Siguenza map (West, 1905), while crude and much distorted, gives soundings which, though few, can be placed with approximate accuracy in the bay and its tidal inlet. Four soundings show the relatively flat floor

of the bay as 11 feet deep. Most of this part of the bay is given on the latest Coast Charts as 11–12 feet below mean low water.[9]

French maps of this region of the period of the La Salle expedition—to which the Cardenas and Siguenza maps belong—such as that of Minet, do not give



2c.—Matagorda (San Bernardo) Bay in 1689. Part of Siguenza map enlarged approximately by 3 with scale and arrow added; some retouching. Lavaca Bay is too wide and short; Sand Reef (Bolton 1924, pp. 179–80) then as now almost closed off Lavaca Bay, but shown too short here. Soundings believed to be in Spanish fathoms (*braza* or double vara) approximately 5.5 feet (1.5 fathoms, 8 ft.; 2.0 f., 11 ft.; 3.0 f., 17 ft.). "Navio quebrado" is small sunken ship of La Salle's fleet, shown just under "N" of "Navío."

soundings over the basin floors, but only along shorelines and in channels.

Confirmation of the relative constancy of bottom depths of Matagorda Bay is also given by the Juan de Langara map of 1799, "corrected in 1805" (Hackett, 1931, map at p. 350). This shows depths from 6 to 11 feet. One sounding seems to

[9] Neither the Siguenza map nor the translation of the description of the itinerary shown on it (West, 1905) refer in any way to the soundings given for Matagorda Bay. The customary unit of sounding then in use in Spanish countries seems to have been the *braza*, or Spanish fathom, with essentially the same unit given as the double *vara* (Hackett, 1931, map at p. 350). The *braza* was 5.485 feet (Haggard, 1941) and two Spanish *varas* equalled 5.556 feet. Either measure may be taken as 5.5 feet. Applied to the soundings of the Siguenza map, the fathom of 5.5 feet agrees closely with modern depths. The Spanish foot, *pie*, was $\frac{1}{3}$ *vara* or 0.926 feet. This unit is evidently too small, as the bays were navigable. The French ships, while relatively small, were heavily loaded and could not have travelled in 2–3 feet of water. Depths of 11 and 16.5 feet, based on the Spanish fathom, were quite adequate.

read 2.5 *brazas*, or 14 feet. With the small number of soundings given, this is adequate confirmation of essential stability of bottom depth from 1689 to the last mapping, 1935.

A map of interest in this study (Fig. 2a) was made by a Captain Monroe in 1833 (Kennedy, 1841; Huson, 1935, p. 4) as he sailed through "Aranzas Bay," including its tributary now known as Copano Bay. The line has two short loops. The ship was aground for a time and the survey was made in December. The closely spaced soundings run longitudinally through Aransas Bay and across the eastern part of Copano Bay to the now abandoned colonial port variously known as Copano Landing, "El Copano," Copano Point, and Powers Point. The point, as mapped, is at the end of Copano Reef and at the foot of a low wooded height of land between Mission Bay and Copano Bay proper (Fig. 3b.)

Superposition of an enlarged reproduction of Monroe's map of Copano Bay on the 1884 edition of the Coast Chart shows that the traverse distance from Live Oak Point to Copano Landing is given by Monroe with an error of only about 14 per cent, a fairly accurate determination considering the crude methods of survey used for such reconnaissance in those days. As might be expected, however, the bearings of the traverse and the sketching of the outlines of the distant shores are not so well done. However, the mapping is good enough to serve to identify such features as Live Oak Point and the opposing Lamar peninsula, the unbroken shoreline from Lamar to Copano Landing, the landing point itself and the unbroken, 3-mile Copano Reef which extends into the bay at right angles from the shore there. Similar errors of shoreline mapping are shown by the Siguenza map of Matagorda Bay in 1689 (Fig. 2c), which shows the bays too wide for their lengths, and omits some striking shoreline features. The Cardenas map of 1690 (Fig. 2b) shows these bays too narrow, but otherwise in remarkably good detail for a reconnaissance. It would seem that the Cardenas map represents the work of a "skilled and careful engineer" (Bolton, 1924, pp. 177–79), while the Monroe map is a sketch made by a ship captain or other ship's officer who had other, concurrent duties which prevented constant attention to traverse observations. However, the log made with the soundings probably represented continuous observation.

Huson (1935, p. 4) reports that the Monroe map

> contains the first known record of soundings for the guidance of navigators entering Copano Bay. The frequently shifting bars soon made it of little use to sailors except to show the general lay of things.

It is now evident that it was map errors that gave the appearance of "shifting bars," and that these errors were large enough to have done so without marked change in the basin's topography.

Comparison between Monroe's soundings and those of the federal Coast Charts shows little recognizable change along the traverse in Copano Bay. It is apparent that Monroe did not happen to locate the few small areas of water slightly deeper than the general floor of the bay shown on the Coast Charts. Nor

did he sound or find bottom in the deep narrow channel between the two bays. In the northern half of Aransas Bay, accepting his soundings as "mean low water," it is definite that 2–3 feet of shallowing has occurred since 1833. Twelve feet of water was general along the 1833 traverse there, according to Monroe's chart, but only 8–10 feet of water has been encountered since that date.

In the southern half of Aransas Bay, the agreement between the 1833 soundings and later ones is good, but shoreline changes have taken place. A total southwestward migration of Aransas Pass tidal inlet along the offshore bar of 2.3 statute miles is recorded between 1833 and 1887, when bank protection and constant dredging fixed the position of the inlet. Since 1833, a large spit has been built out into the bay, converting 5 miles of the southern end into a cove. The formation of the spit offset enlargement of the bay in inlet migration. Monroe's chart does not reveal important changes in oyster-reef location, if we assume that his mapping of reefs east of Copano Reef was based on occasional exposures of summits rather than on continuously visible reefs.

For Green Lake, Calhoun County, noted in the graph (Fig. 5), the shoreline was measured from United States Army aerial photographs of 1940 and the single sounding was made by the writer about ¼ mile from shore. It is probably not the maximum depth, but is likely to be within 1 or 2 feet of it.

The southern end of Laguna Madre at the Rio Grande delta is shown on aeronautical charts of the United States Bureau of Air Commerce of 1935 as more restricted by encroachment of surrounding tidal flats than in the 1917 edition of the Coast Charts of this area, basic survey for which was made in 1867. The newer mapping is used with the old soundings, which may not be correct for 1935.

For a few of the Louisiana basins studied the latest, detailed charts were not at hand and either the general charts for the coast or the United States Engineer's Map of Southern Louisiana, 1934 and 1938 editions, were used.

Tides and storms.—The tides in the lagoons, bays, and tidal lakes of the northwestern coast of the Gulf of Mexico are of two kinds, the normal "Gulf" or gravitational tides of the sun and moon series, and wind and storm tides. The normal "Gulf" tides have a maximum range of about 4.0 feet at the outer shoreline, high tide ordinarily occurring once in a lunar day. In the bays, the tide is less, but appreciable normal wind tides are said to reach 0.5–1.5 feet. They occur irregularly, but the dominant north winds of winter blow high water to the southerly parts of bays and out into the Gulf, while the southeast, onshore winds of the coast southwest of Galveston in the 9 warm months blow high water north into the inner tidal basins. The normal winds are seen to be monsoonal on the Texas coast. The onshore winds are ordinarily regularly active from early or mid-morning or mid-day to early night each day for about 7 months, less regular for the rest of the 9 warm months.

The highest waters in the basins occur during storms. The "northers" of winter make the tidal inlets run like rivers in flood, and several feet of high water then comes to the southern parts of bays. The "tropical disturbances" and Gulf

cyclonic storms with their more violent variety known as "hurricanes" move northwestward and northward in the Gulf and send a high tide ahead of them over wide areas. Tides of 3–4 feet occur along considerable lengths of the shoreline when hurricanes are in the same section of the Gulf. In and to the right of the path of the storm itself, the storm tide may reach as much as 25 feet at the Gulf shore and 10–12 feet as far as 15–20 miles inland in the larger bays. The distribution of these storm tides depends on the winds of the hurricane which shift with the progress of the storm.

From a study of the record down to 1934 (Price, 1936), a given point on this coast probably experiences as many as 7 or 8 hurricanes and 20 or more Gulf storms per century. Of these 27 or 28, possibly 2 will develop tides of maximum height.

For much of the year, this coast is out of the path of the strong westerly winds and storms characteristic of much of the continent. They visit the Louisiana coast except in 4 or 5 of the warmer months, but most of the Texas coast receives them only from December to March. However, the heavy air of cold winds exerts more pressure than the lighter air of warm winds. Hence, winter winds probably develop larger waves than summer winds of equal velocity.

Climate.—For the purpose of this study, the Thornthwaite (1931, 1941) climatic mapping (Fig. 1a) is useful, as well as Visher's collection of charts (Visher, 1945). The coast east of Brazos River is humid, that southwest of it is sub-humid and semi-arid. The southwestern coast receives less precipitation, smaller run-off (Visher, 1945, Fig. 14) and silt-load from rivers and other drainage courses, and has higher evaporation. The eastern coast has more and larger rivers and other streams, more run-off and silt, more precipitation and less evaporation. In Texas ice has been reported on tidal water bodies, but is a rare occurrence.

Because of high evaporation and low water-tables, completely enclosed lakes south of Baffin Bay are intermittent, unless their basins reach the permanent ground-water level, in which case they are commonly highly saline.

The greater run-off of the rivers of the eastern, humid coast is commonly associated, according to incomplete data in hand, with greater silt-load.[10] Although low waters may be clear, flood waters will be sediment laden. The run-off, and presumably also the silt load, is greater for the streams of larger drainage area. There is a regular rapid decrease in run-off per unit of drainage area southwestward along the coast of Texas (Price, 1933a, Fig. 5) and a less regular decrease in total run-off.

[10] Figures collected some years ago are as follows. While some may be subject to correction by later studies, the general proportions are not likely to be wrong. Figures are thousands of acre-feet of sediment per year.

Deltaic:	Mississippi	Brazos plus Colorado	Rio Grande
	170.0	16.2	19.7
Embayed:	San Antonio	Nueces	
	0.2	0.5	

These figures are from Faris (1933) except for the Mississippi. They are in rough proportion to total run-off at head of tide water and delta size.

HISTORY OF COAST AND BASINS

Résumé of Quaternary history of tidewater region.—Since the beginning of the Tertiary, the Gulf Coastal Plain has been slowly tilting toward the Gulf and successive belts of land have been added along the shoreline. This history continued throughout the Pleistocene (Doering, 1935). During the Pleistocene there were eustatic oscillations of sea-level in the amount of several hundred feet each, the so-called glacial-control sea-level oscillations.

The Quaternary formations of Louisiana (Russell, 1940) are five in number, including the Recent. Each is a high sea-level deposit and each, except the last, has been entrenched by the rivers adjusting their valleys to the next low sea-level position. Upon the return of sea-level to a high position after each entrenchment, the valleys became filled with alluvium.

During Beaumont time, two high sea-level deltaic formations were deposited on the Gulf Coast (Russell, 1940; Price, 1939) separated by the shoreline terrace —Ingleside (Price, 1933b)—of the older. The last entrenchment developed gorges through the latest Beaumont deltas (Prairie of Louisiana).

During the Recent, the rise of the sea drowned the gorges and they have now been filled to sea-level with the extension of deltas to the coastal lagoon or the Gulf by the largest streams—Mississippi, Rio Grande, Brazos-Colorado, Apalachicola, Pearl, San Fernando. Lesser streams either have no deltas at present or only small, bay-head deltas. The bay-head deltas are, however, the active depositional units which have advanced the alluvial valleys, plains or floodplains to the heads of the bays.

The lesser streams of the coast have filled all but an insignificant vertical amount of their drowned valleys. If the last entrenchment was 240–250 feet, or as much as 350–450 feet as recently estimated (Fisk, 1944, p. 68), the 16.5 feet remaining to be filled in Corpus Christi Bay before recent engineering activity changed the natural bottom depths, was only about 5–7 per cent of the depth originally required to be filled. While the embayment of the valley must have been for many miles inland,[11] a length of only 26 miles remains to be filled and to an average depth of perhaps only 8 feet. The 26-mile embayment remaining is probably a small part of the original distance of drowning of the valley. However, the additional amount of sediment needed to advance the alluvial valley fill to sea-level at the coastal lagoon or Gulf shoreline is much larger than the volume of the bays in the valley, because the filling would be done by raising the grade of the river for a very long distance inland. The present grade near the coast is 1 foot to 1 mile. Conditions are similar in the other deeply embayed valleys.

Russell and Howe (1935) show that the Mississippi delta—that is, the active subdelta—has shifted back and forth along the coast during the late Recent. When it had western positions it developed the western coast of Louisiana, building it out. When it shifted east, the western coast was, they think, recessed by

[11] Possibly to 100 miles from the present shoreline.

sinking and wave attack with the building each time of a beach made of the coarse residuals of the delta materials which were being eroded. This has produced, they believe, the striking series of long, parallel to slightly diverging, sandy beach ridges—locally called cheniers—which characterize this coast. Strips of marsh separate the cheniers (Fig. 1b).

Sinking of this coast has, Russell and Howe (1935) believe, caused groups of lakes which occurred between beach ridges to join and become greatly enlarged, producing the large coastal bays of the Achafalaya, Côte Blanche, and Vermilion group and lesser lakes. These lakes, they report, are "said to be rapidly enlarging" and the shore "in very rapid retreat." The writer has not studied this coast in detail or attempted to compare maps made at successive dates to verify or determine the rate of this recession and submergence.

Recent history of basins.—Without more extensive study of recorded soundings at different dates with their relation to mean sea-level, and of cores through basin sediments, no detailed historical account of changes in the basins in Recent time can be written. Such logs of holes drilled in the bays as have come to hand show significant stratification and deeply buried shell beds.

It is known that sharp shoreline changes have occurred during major storms, —the hurricanes or Gulf cyclones. For example, a strip reported as 140 feet wide was removed from great lengths of low shorelines of Corpus Christi and adjacent bays in a hurricane in 1919. The writer has observed additional retreats of several feet in lesser storms. A total of about 120 feet is reported to have been lost by the eastern shoreline of San Antonio Bay in about 40 years. A considerable part of the townsite of Indianola, a colonial port of Calhoun County, has been lost to Matagorda Bay and Powderhorn Bayou since 1873, mostly during hurricanes. Some of this loss occurred in 1945, part of the site of an Army Camp near Indianola being washed away.

Some protected shorelines, such as many along the coastal lagoon, prograde by the deposition of nearshore spits and bay mouth bars, with the growth of marsh in the coves so formed.

Warping, with subsidence or tilt of the land, deepening some basins, has occurred in large and small areas on the Texas Coast during the Recent, it is believed. Galveston and Corpus Christi bays show marked geomorphic evidences of subsidence during the late Recent, but it is not known to what extent the intervening coast was affected. Geophysicists estimate that there has been a eustatic rise of sea-level at the rate roughly of about 10 centimeters (4 inches) per century in recent decades (Gutenberg, 1941; Marmer, 1943) and that the coast of the Gulf has suffered regional tilt, producing a total rise of sea-level (local plus eustatic) of about 38 centimeters (15 inches) in the past century (Gutenberg, 1941, Table 8, p. 744) as measured at Galveston. Their assumption of regional tilt is not based on detailed data between tide-observation stations.

Subsidence and tilt in the Mississippi delta has been commented on by Russell and Howe (1935), H. N. Fisk (1944), and by R. J. Russell (1936, pp. 162–76).

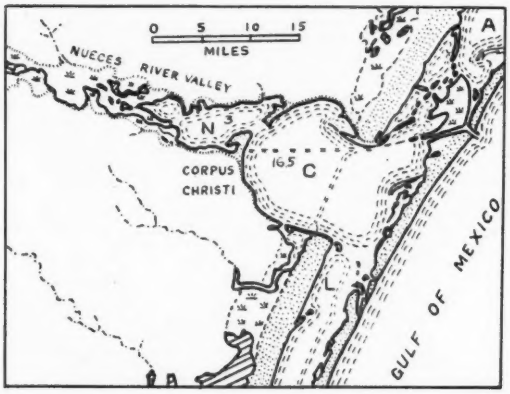
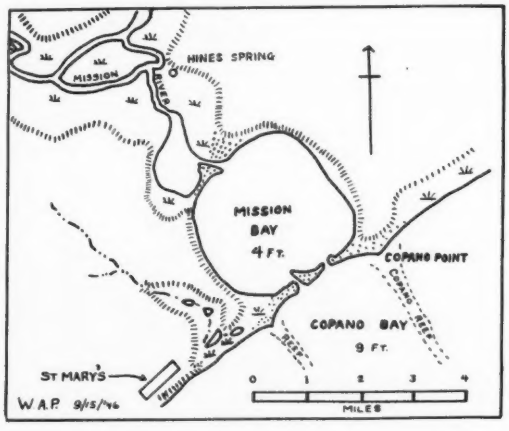


FIG. 3.—Segmentation of embayments in drowned stream valleys, Texas.

3a.—Nueces River valley and vicinity. Hachures mark bluffs. N, Nueces Bay in two segments, maximum depth 3 feet. C, Corpus Christi Bay, with ship-channel spoil banks forming 3 artificial segments. Former maximum depth 16.5, now 14 feet. A, south end of Aransas Bay segment of coastal lagoon, with Harbor Island tidal delta and Aransas Pass inlet south of bay. L, Laguna Madre, north end, with 3 positions of Corpus Christi Pass, now closed. Recent offshore bar, stippled, shows Mustang Island and parts of St. Joseph at north and Padre Island at south. Ingleside Pleistocene offshore bar, also stippled, is barrier for consequent drainage of Montgomery Beaumont delta of Nueces River. Port Bay and associated lakes at north edge of map, Oso Creek at south, are embayments of entrenched creeks of Ingleside lagoon terrace, the latter shown by marsh convention. Intermittent lake at south edge of map is Laguna Larga.



3b.—Mission River valley. From junction of Melon Creek to mouth. Hachures mark bluffs, with intermeander spurs along valley wall. Segmentation by sand spits and bars. Copano Bay entrenched in Ingleside lagoon terrace. Reefs are Recent sand bars bearing oysters. St. Mary's and Copano Point (El Copano), abandoned colonial settlements. Hines Spring is from outcrop of coquina of early Montgomery Beaumont embayment of Ingleside lagoon, now covered by deltaic sediments of later Montgomery time.

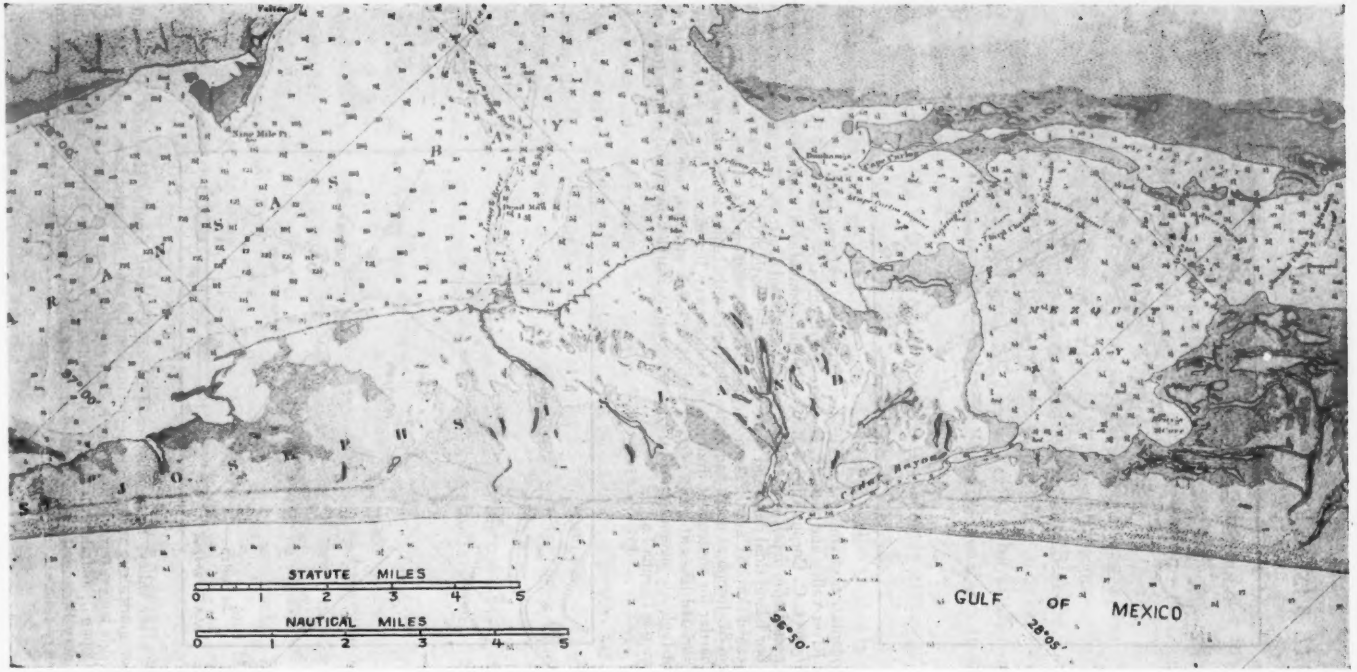
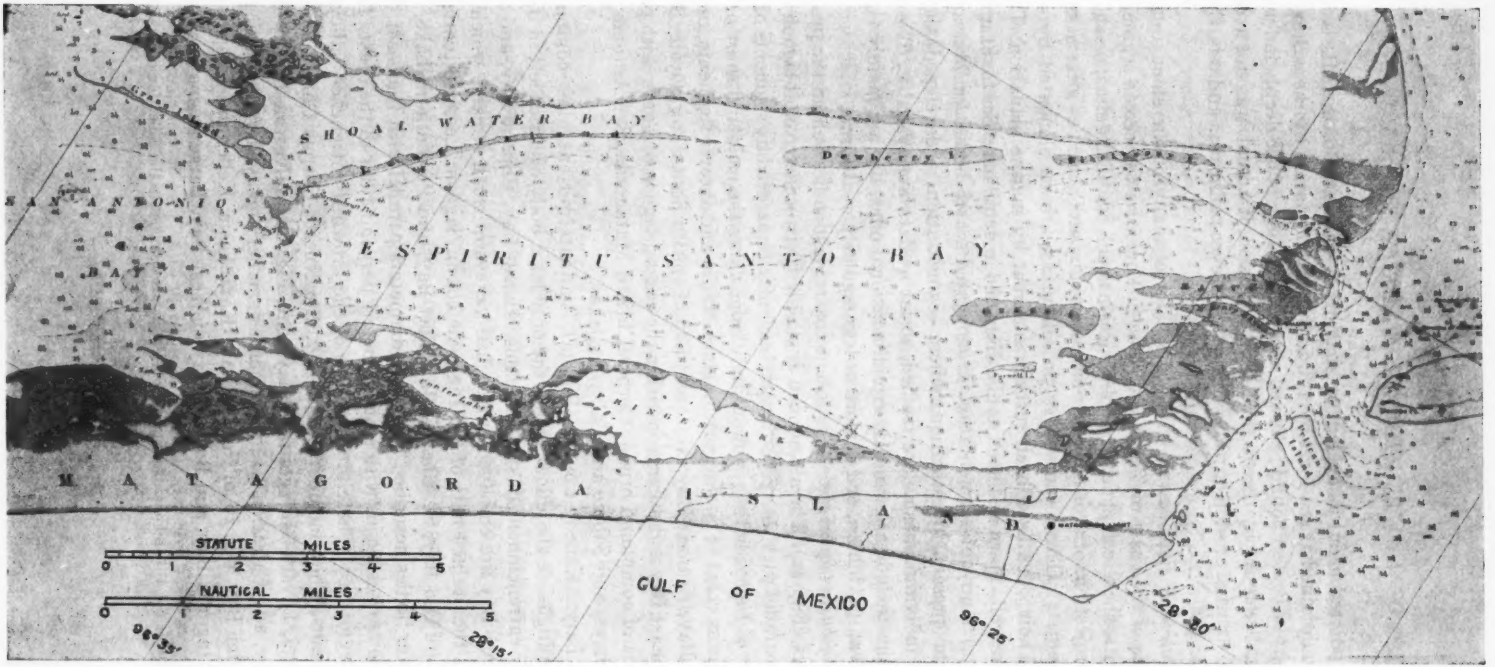


FIG. 4.—Segmentation of coastal lagoon between Matagorda and Aransas bays, Texas. From early charts, slightly retouched with some explanatory matter added. Soundings in feet to 19 feet; below in fathoms.

4a.—Combined washover-fan and tidal delta topography on St. Joseph's Island and Matagorda Island on both sides of Cedar Bayou Inlet. Segmentation in Aransas and Mesquite bays by spits, bars, and oyster reefs. Beachridge topography on recent bar. Ingleside Bar forms mainland coast. From Coast Chart 209, 1884 edition.



4b.—Asymmetrical tidal delta at Pass Cavallo and strong development of spits and spit-formed bars. Dominant southwest drift of sediment-laden currents indicated from Matagorda Bay (at extreme right) into and along Espiritu Santo Bay. From Coast Chart 107, edition of 1872. Depths in Pass Cavallo in feet to 19 feet; fathoms to 5.5 fathoms (33 feet) west of Pelican Island.

The latter pointed it out as evident in abandoned sub-deltas of the Mississippi, no longer maintained at sea-level by alluviation. Examination by the writer of a colonial chart of Breton Sound[12] showed marked recession of the deeply indented, deltaic north shoreline by recent time. This recession, if actual, was not accomplished by extensive erosion of projecting natural levee peninsulas and was, therefore, by tilt.

Segmentation of tidal basins.—It is the habit of many of the elongate tidal water bodies of the coast of Texas and some in Louisiana to become segmented by bars, spits, shell reefs, and large obstructions such as tidal deltas, washover fans, and projections of drowned and embayed valley walls, such as intermeander spurs (Figs. 3, 4). These spurs have, in many cases, been elongated by spits (Fig. 3a). Their sides have been further undercut by marine planation. These processes are well known and need not be discussed in detail here. See for example, Raisz' (1934) study of segmentation in elongated water bodies in Massachusetts. In the present investigation, where segmentation is developed significantly, the individual basins are studied, so far as data are available. The segmented basins include a few nearly equidimensional ones, but are mainly (1) irregularly oval, (2) lobate, or (3) more or less regularly oval forms.

Classes of basins by origin.—The recent coastal lagoon lies behind the present offshore bars (Fig. 1a). The abandoned Ingleside Pleistocene coastal lagoon segments run parallel with the recent lagoon back of it, separated by segments of the offshore bar of Ingleside time, now a sandy ridge along the mainland shore of the southern Texas coast (Figs. 1a, 3a). Laguna Madre and shorter segments known as Redfish Bay, Aransas Bay, Mesquite Bay, Espiritu Santo Bay, Oyster Bay, West Bay, East Bay and others constitute the coastal lagoon of Texas, with parts of the basins of compound origin: Corpus Christi, Matagorda, San Antonio and Galveston bays, and Sabine and Calcasieu lakes.

Laguna Larga, Kenedy County (Fig. 3a), is an intermittent lake—commonly dry—in the Ingleside shoreline lagoon, the only large body of water left in it not modified by entrenchment of small streams. Alazan Bay, Copano Bay, and part of Matagorda Bay are embayed entrenched valleys of small streams which ran in or across the drained flats of the Ingleside coastal lagoon. Lesser estuaries in these flats are Oso Bay, St. Charles Bay, Port Bay, and Powderhorn Lake.

The water bodies described have long diameters parallel with the coast. The next class comprises basins with long diameters perpendicular to the coast. They are much segmented. These are the bays of the drowned entrenched valleys of master streams. They include: Baffin Bay, the Nueces-Corpus Christi embayment, Fig. 3a, Lavaca-Matagorda embayment, Fig. 2b, Galveston-Trinity Bay, Sabine Lake, and Calcasieu Lake. Numerous smaller embayed-valley basins include: Mission Bay, Fig. 3b, of Copano Bay; Karankawa, Keller and Trespalacios bays of Matagorda Bay, and Bastrop Bay of West Bay. Large basins in alluvial

[12] This chart is not at hand at this writing for reference. It was once in the collection of Donald C. Barton.

valleys more or less enclosed by floodplain materials include Green and Mission lakes on Guadalupe River and several on San Jacinto and Trinity rivers.

The origins of the bays and lakes of the Mississippi delta according to Russell and Howe (1935) have been discussed. They believe regional tilt, local subsidence, and marine planation to have been active. If so, these processes may have destroyed specific evidences of the original forms of many of the basins.

Long stretches of the coastal lagoon are filled to sea-level. East of the East Bay section which opens into Galveston Bay, the former coastal lagoon—in a humid region—is filled to the Louisiana state line, and into that state by marsh. South of Baffin Bay—in semi-arid territory—much of the coastal lagoon is a bare, sandy mud-flat stretching to central Kenedy County. Marsh occurs in southern Texas behind nearshore spits, where the writer has seen it from the air from Espiritu Santo Bay to Corpus Christi Bay. In Louisiana, the cheniers in the marsh represent former beach ridges, possibly not former offshore bars, though some may have held this position. Thus, Grand Lake, West Côte Blanche, and the inner part of Vermilion Bay may have had such a position (Fig. 1,b).

Directions of long diameters of basins.—Erwin Raisz (1934) believed that the long diameters of small rounded to oval lakes and lagoons of the coastal plains of Massachusetts tend to be parallel with the directions of the greatest wind velocities. No such tendency is noted in the large tidal basins of Texas here studied.[13] Long diameters are here controlled in most cases by the long diameters of the ancestral major geomorphic features of which the basins are a subsidiary part, such as the entrenched valleys and coastal lagoon. The lakes of the Louisiana coast have not been critically studied by the writer in relation to winds, but the control of ancestral topography is evidently dominant there in some of the larger basins, at least.

WIDTH-DEPTH RATIOS IN TIDAL BASINS

Selection of dimensions of basins.—As a part of the study of the form, history of, and the forces active in, the tidewater bodies on the Texas coast, the writer formerly attempted an analysis of the ratios of width to depth (Price, 1933b, Figs. 2, 7, pp. 931, 932). This study seemed to show the occurrence of a roughly constant ratio of 1 mile to 1 foot and to point to some significant interpretations which might be made of it.

In the previous study, the writer used the northwest-southeast diameters to represent width, with the idea that these might be representative of the developmental processes of the basins in view of the southeast wind of the southern coast of Texas being the strongest (Price, 1933b, Fig. 9).[14] It has since been realized that the attainment of rounded to oval form in bays is probably associated with the

[13] The rather complex wind pattern of southern Texas seems to have controlled the shapes of many fresh-water lakes.

[14] The formula for "strength" used in Figure 9, here cited, has been abandoned as incorrect, but the southeast wind seems to be the resultant of the coastal winds of the dry, hot parts of the year.

blowing of strong winds from numerous directions, as suggested by Raisz (1934. p. 846). Lack of a wind-controlled direction of elongation on this coast suggests the use of average widths. If a single diameter were used, different ratios would be obtained for different parts of the same oval basin and for different sections of a long coastal lagoon. In the present study (Table I and Fig. 5), a so-called average width is used and is studied in relation to maximum bottom depths, as in the 1933 study, exclusive of tidal and artificial channels.

The widths selected from which to derive the "average width" are: (a) the longest diameter; (b) the longest "short" diameter measured approximately at right angles to the long diameter. The average of the long and "short" diameters is used as "width," or "average width."

It has been said that there can be no value attached to small fractions of a mile in these measurements. This is because of (1) irregularities in shoreline, and (2) doubt as to the effective shoreline or edge where the margin of the basin is marshy, and (3) uncertainty in the position of termination of "open water" where an end of a bay is broken by bars and spits, and (4) the question as to whether to use the summit or flank of a segmenting and irregularly submerged reef. The diameters measured are not in all cases at right angles to each other, but are all measured at large angles between 45° and 90°.

The depths used are the maximum depths shown in the main bottom areas of the basins not including channel depths. Limitations in the accuracy of the determination of depth have been discussed previously. The basins are revealed by the soundings to be saucer-shaped or broadly trough-shaped. The margins slope gently toward the central parts of the bays from their low beaches. The main areas of the larger basins are relatively flat with only a few feet of relief other than that of reefs, projecting spits, and enclosing bars. The main areas of the basin floors are in most cases 1–3 feet shallower than maximum depths.

Channel depths are in many cases much deeper than the bottoms of the basins. The range in depth for the basins surveyed is from 3 to 16.5 feet, while tidal inlet channels in the natural state within the areas of the offshore bar reach depths of 43 feet without dredging.

In some places, natural channels are found in the bays or at the junction of bay segments where they have been scoured out between islands or bars. These channels may have as much as twice the depth of adjacent basin bottoms.

Development of width-depth graph.—By using average widths in miles and maximum depths in feet, points for 31 basins have been platted on a graph (Fig. 5). Table I contains the data used. Widths are measured on the horizontal axis and depths on the vertical axis, with the point of origin, or zero, at the upper left. The 31 basins are found to be scattered through an angular sector of 32° between the limiting straight-line ratio lines of

W/D, 2.2/1 to 0.67/1 in miles/feet
12,000/1 to 3,500/1 in equal units (feet/feet).

The range of depths is 3 to 16.5 feet, and of widths 2 to 29.5 miles.

TABLE I

AVERAGE WIDTH AND MAXIMUM DEPTH IN 31 TIDAL BASINS OF TEXAS AND LOUISIANA

No.	*Bay and Segment (Entered by river, R)*		*Maximum Diameters (Statute Miles)*	*Average Width (Statute Miles)*	*Maximum Depth of Basin Floor (Feet) (Datum: Mean Low Water)*	*Dates of Chart Editions (D, Survey Data)*	*Remarks (Dates are of Basic Hydrographic Surveys)*
	NON-HUMID COAST						
1	Aransas Bay		6.8×12.0	9.4	a. 12.0*	1833	Capt. Monroe
					b. 14.0	1924	1856–8, 1869, 1875, 1934–5
2	Copano Bay	R	5.7×14.2	9.9	a. 9.5	1890	1856–58, 1875
					b. 8.0	1935 D	1935
3	Corpus Christi Bay		11.8×15.0	13.4	a. 16.5	1872	1868–9
					b. 15.0	1926	
					c. 15.5	1935 D	1934–5
4	Espiritu Santo Bay		4.3×14.0	9.0	a. 8.5	1872	1856–8
					b. 8.0	1935 D	1934–5
5	Green Lake		2.8× 4.7	3.7	4–5?	1946 D	Sounding ¼ mile out. W.A.P.
6	Karankawa Bay		2.7× 8.0*	5.3	7.0	1922	Through 2 segments. Creek enters bay. 1868–71; 1934–5
7	Keller Bay		3.0× 3.7	3.3	5.0	1922	Creek enters bay. 1868–71; 1934–5
8	Laguna Madre, (N. of Port Isabel, S. end)		4.3×10.0	7.1	6.0	1917	Soundings 1867
						1940	Mapping of enclosed flat with out soundings. Possibly no resurvey
9	Lavaca Bay, North	R	4.6× 4.8	4.7	6.0	1922	1868–71; 1934–5
10	Lavaca Bay, South		5.3× 8.6	6.9	8.0	1922	1867–71; 1934–5
11	Matagorda Bay West		12.5×17.0	15.0	a. 11.0*	1690	Siguenza map, 4 soundings
					b. 14.0	1872	1856; 1860; 1866–71
					14.0	1935 D	1934–5
12	Mesquite Bay		3.0× 4.0	3.5	5.5	1890	1856–58; 1875; 1935
13	Mission Bay (Refugio County)		2.8	2.8	a. 3.5	1890	1875
					b. 4.0	1935 D	1935, partial
14	Nueces Bay	R	3.3× 8.7	6.0	3.0	1926	1882, partial. Segmenting (?) Oyster reefs not mapped
15	San Antonio Bay (N. of Mosquito Point)	R	5.2× 8.5	6.8	a. 6.0	1872–1880	1856–58
					b. 5.0	1935 D	1935
16	W. of Panther Reef		6.6× 9.0	7.8	a. 6.7	1872–1880	Do.
					b. 6.5	1935 D	
17	E. of Panther Reef		5.5× 6.6	6.0	a. 6.7	1872–1880	Do.
					b. 6.0	1935 D	
	HUMID COAST						
18	AchafalayaBay	R	10.0×22.0	16.0	9.0	1944	1858–9; 1909
						1935	
19	Bastrop Bay		2.3	2.3	3.0	1934 D	Entered by creek. 1934
20	Borgne, Lake	R	10.7×23.5	17.1	9.0	1944	1857; 1870
21	Calcasieu Lake	R	6.0×15.0	10.5	7.0	1934	1933–4
22	West Côte Blanche Bay		9.3×15.7	12.5	7.5	1934	1886; 1935
23	Galveston-Trinity Bay	R	16.2×24.1	20.1	9.0	1936	History of silting by bay-head delta, charts of 1872–1936. Surveys: 1852–5; 1931–4
24	Maurepas, Lake	R	9.0×12.5	10.7	12.5	1944	1899
25	Oyster Bay		2.1× 4.3	3.2	4.0	1934 D	Entered by creek. 1934
26	Ponchartrain, Lake	R	24.0×35.0	29.5	16.5	1944	1871; 1897–8
27	Sabine Lake	R	7.0×17.0	12.0	8.0	1923	1885
28	Salvador, Lake		7.1×12.8	9.9	8.0	1934	Received flood waters in natural state? U.S.E.D. Chart 1934 edition
29	Turtle Bay		2.8× 3.2	3.0	5.0	1936	Cut off by bay-head delta 1931–4
30	Vermilion Bay	R	11.4×20.0	15.7	10.5	1944	1888–9
31	White Lake		6.0×14.0	10.0	5.0	1934	U.S.E.D. Chart, 1934 edition
	BAY SEGMENTS ARTIFICIALLY PRODUCED BY SPOIL BANKS OF SHIP CHANNELS						
3d	Corpus Christi Bay, Northwest segment		4.7× 9.2	6.9	14.0	1943	
3e	Southwest segment		7.0× 8.1	7.5	13.0	1943	
3f	Southeast segment		6.0×10.8	8.4	13.0	1943	

* Probably not the maximum depth.

In the graph (Fig. 5). some older depths, selected to show the range in depths observed, are platted with crosses. These do not constitute a full record of former depth determinations and are not given for all basins. Basins known to be receiving alluvium directly from rivers or large creeks are marked by an extra circle. A few small basins tributary to Matagorda Bay in which the creeks are

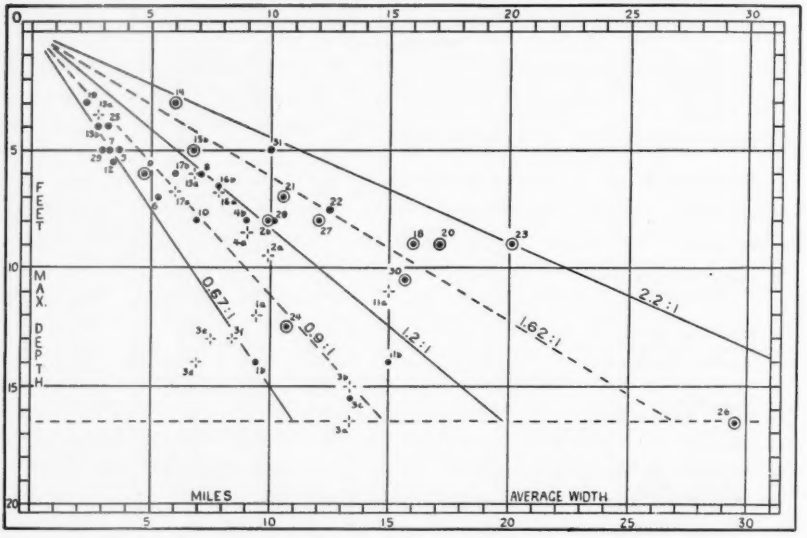


FIG. 5.—Average width and maximum depth in 31 tidal basins of Texas and Louisiana coasts. Data from Table 1. Solid circle, basin not receiving alluvium directly; with outer circle, receiving it directly. Cross, depth from survey before latest, except 3d–f, artificial segments of Corpus Christ Bay. Values on ratio lines in feet to miles. Average ratio lines broken. Shallow sector, 2.2:1 to 1.2:1, has mainly alluviated basins of humid region. Deep sector, 1.2:1 to 0.67:1, has mainly non-alluviated basis of non-humid coast. Regional wave-base for tidal basins, 16.5 feet.

long, narrow tidal estuaries, are not shown as alluviated, as it was uncertain to what extent they might be receiving alluvial sediments directly.

In Table I, the basins are separated into two groups, those of the humid coast of Louisiana and eastern Texas, and those of the non-humid coast of central and southern Texas. Most of the basins of the humid region fall within a shallow sector of about 15° delimited by the width:depth-ratio lines of 2.2:1, and 1.2:1, with an approximate average line of 1.62:1. This sector also holds most of the alluviated basins. Likewise most of the basins of the non-humid coast fall in a sector of about 17°, deeper than the first and adjoining it, in which only a few alluviated basins lie. It is limited by the ratio lines of 1.2:1 and 0.67:1, with 0.9:1 as an approximate average.

The dispersion of points in Figure 5 is rather wide, and the division into sec-

tors only approximately separates the basins on a regional basis, or by the criterion of alluviation or non-alluviation. A better analysis is made by constructing two regional graphs (Figs. 6 and 7). The same conventions are used as in Figure 5. The dispersions of the points are reasonably small in each graph, and statistical

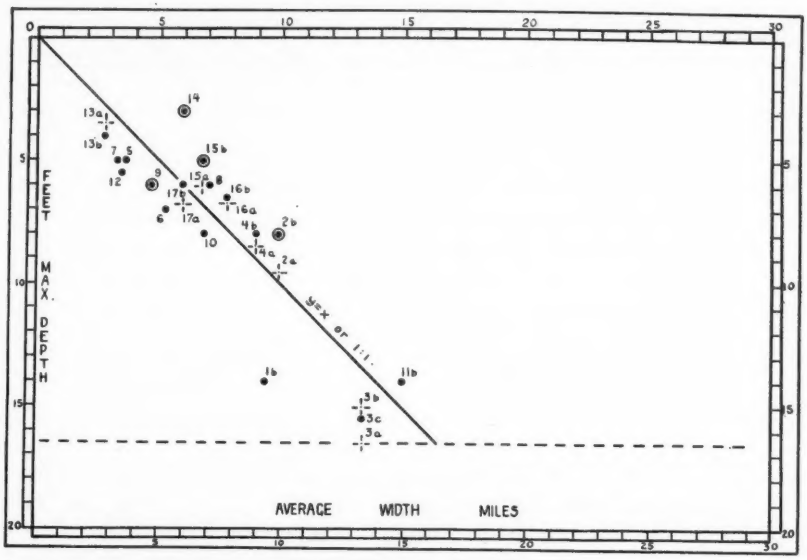


FIG. 6.—Basins of non-humid coast: average width to maximum depth. Ratio line of 1 mile to 1 foot (1:1, or $y=x$) is average line for point dispersion. Symbols as in Figure 5. Bay 14 incompletely mapped, probably segmented by reefs. Bay 1 is only aberrant basin among those with soundings available.

analysis by least squares shows that each satisfies the equation of a straight line fairly closely.

In Figure 6, for the non-humid coast, the average straight line used is the width-depth ratio 1:1, in which y feet $=x$ miles. The dispersion of the points from the average line is 2.0 feet or less, except in two instances. In all but two out of seven basins for which earlier maximum depths are platted the older figures are closer to the average than are the later depths.[15]

In Figure 7, for the humid coast, the straight line, $y=0.41x+3.0$, is the aver-

[15] The ratio line of 1:1 is used instead of the theoretical best line using the least squares method because 1:1 is a simpler line to compute, it begins at the origin and is so near the theoretical best line that it requires more precise work than the data justify to determine which has the smaller total departure. The one strongly aberrant bay, 1b in Fig. 5, if reduced to average, would equalize the difference between the two lines. The least square line is $y=0.91x+0.92$. It has a coefficient of correlation of 0.85 for the graph (Fig. 6).

age and the dispersion is small. With one exception, the departures are -1.25 foot or less and $+2.25$ feet or less. The exception, No. 24, is 5.0 feet deeper than the average. If this aberrant basin is disregarded, the average line lies about 0.6–0.75 foot higher and the dispersion would have the same range above and below the line. The equation[16] would be close to $y=0.41x+2.3$.

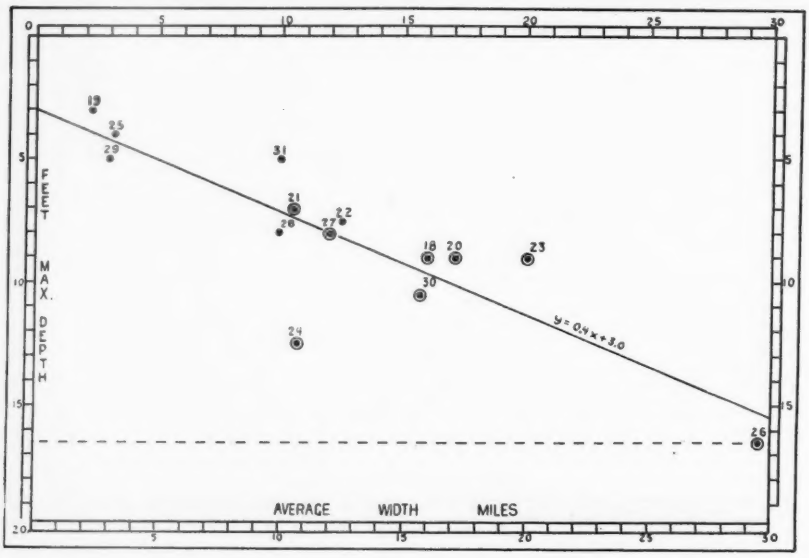


FIG. 7.—Basins of humid coast: average width to maximum depth. Line: $y=0.4x+3.0$ is least-square average for point dispersion. Symbols as in Figures 5 and 6. Not all tidal basins of Louisiana included.

Since soundings for basins narrower than 2.25 miles are lacking, it is not known that the small lakes and tidal basins follow the average lines here developed.

Climatic basis of segregation of basins for analysis.—This segregation provides a contrast in rainfall, evaporation, wind patterns, storm incidence, stream run-off, and silt load. It contrasts basins by regions in which the diastrophism may vary appreciably. Such a classification may not be the only one which would throw light on the laws of basin existence, but it seems to satisfy the immediate needs of this study.

Microclimatic mapping would probably show humid climate to extend southward along the immediate coast in a narrow belt from the position of the boundary shown in Figure 1a but would probably not affect any of the present con-

[16] This equation has a coefficient of correlation of 0.858 when the constant is 3.0 and would have a higher correlation still with the smaller value of 2.3.

clusions. Matagorda Bay and its branches would probably be found to be a marginal climatic area, as, indeed, it should be considered on the basis of present mapping.

EQUILIBRIUM OF FORM AND FORCES IN TIDAL BASINS

Equilibrium indicated by linear grouping of basins in graphs.—The narrow limits of dispersion of the points platted in Figures 6 and 7 and their adherence to a single straight line in each indicates that there has been an equilibrium of forces currently and normally affecting basin shape. The few erratic basins suggest the occasional operation of forces not in equilibrium.

Because the number of basins on this coast is not very large, and because depth figures are not available for all of those mapped, the validity of the two regional groupings can not be rigidly proved by statistical mathematics. However, for the lines drawn, the linear correlations are high, showing that the equations are valid for the data available. Also, the departures from linearity are within the limits of incidental scour and fill indicated by depths measured at different dates, such as the pairs: 2a, b; 4a, b; 15a, b and 17a, b.

Forces operating to shape tidal basins.—These may be classified as *interior, exterior, "normal"* or *continuing*, and *occasional*. The "normal" forces of the basins are the interior, continuing forces such as tidal currents, waves and wind-driven currents, gravitational settling of sediments, chemical precipitation growth of bottom-dwelling organisms with accumulation of the hard parts of other organisms, and the effects of rainfall and wind on the immediate basin margins which extend above water. Normal or continuing exterior forces which affect interior conditions are floods and river currents.

Occasional forces affecting basin form are exterior forces. These include the effects of diastrophism and storms. Storms, chiefly the hurricanes and other tropical cyclones, bring high tides, great waves, and occasional great floods of water from the Gulf. Eustatic sea-level change is an exterior condition affecting the interior basins. It may be continuing or occasional.

The different groupings of the basins of the humid and non-humid regions indicates that there is a difference in the relative strengths of the forces now in operation in the two regions. Variations in the forces and conditions affecting basin shape during the past have doubtless produced historical differences in the equilibrium attained at different times.

Since the equilibrium of forces of the basins affects only the interior forces, and such materials as are regularly delivered to them by continuing exterior forces, the occasional exterior forces tend to overcome the equilibrium for a time and produce sudden change of form. If these changes are not too great, the operation of the normal equilibrium will continue and again restore a characteristic ratio of width to depth, if the previous dimensions have been altered. Therefore, for our immediate purposes change of size is not as important as change of ratio. A change of ratio shown by numerous basins in the same region in-

dicates that some factor has changed so as to upset the previously existing equilibrium. Such a condition is indicated by a shallowing of many basins of the non-humid coast during late historic time for this coast.

The too strong operation of occasional forces may cause extinction of tidal basins, as by the filling of sections of the coastal lagoon by wind-blown and flood-washed sediments, and by depression of the coast so as to drown or widely breach offshore bars. Such events have affected parts of the coast studied.

Relation between depth of wave action, width of basin, and fetch of wind.—The existence of a relatively constant ratio of average width to maximum depth in the basins of a region of relatively uniform conditions of bed and bank materials, incoming sediments, and climate seems to indicate certain genetic relationships between basin shape and the forces of bottom excavation. This is the main thesis of this study. It is possible that a more extended analysis of basin dimensions and form might disclose other relations bearing on this subject. With the dimensions chosen and the methods of statistical analysis here employed, there seems to be a relationship which is geologically significant. These conclusions are strengthened by the change in ratio from the non-humid to the humid region.

In order to study this genetic relationship a digression to consider terminology seems advisable.

The term *wave base* seems to have two usages, the depth of determinable orbital motion in the wave and the depth of effective wave scour or planation. The maximum depth to which loose sediment may be set in motion in a given basin by its waves may, it would seem, possibly not in all cases be that of effective wave planation in the basin. The character and abundance of the incoming sediments —including oyster shells—and of precipitated chemicals might—once they had settled to bottom—produce a resistance to planation in the basin at levels above the maximum possible depths of agitation of water. Be that as it may, the use of the term wave base in this study is that of the effective planation of the basin bottom under the existing local conditions and those which have existed during the life of the present basin floor.

The term *basin*, as has been said, is here applied to the portion of an enclosed body of tidewater which has basin shape, that is, the open-water area not subdivided by bars, spits, islands, and other significant under-water elevations. Such areas of open water in the tidal water bodies of this coast commonly have basin shape.

The *fetch* of the wind, or of a wave, or wave formation, is the distance of its propagation to leeward of its point or line of origin. Thus, the fetch of wave propagation in a tidal basin in a given direction is the width of open water in that direction, the waves being formed and driven by the moving air carried across the water surface of the basin in wind motion.

It is said by textbook writers that the depth of the wave base considered as the depth of orbital motion is equal to the distance between successive wave crests, the wave length. Also that the greatest waves are developed in the prac-

tically unlimited expanse of the open sea. The maximum wave lengths and wave-base depths given seem to be about 600 feet. It is evident that, if the maximum wave base of effective scour in the largest tidal basins of the coasts here studied is that of their maximum depths—16.5 feet—the effect of the surface winds in producing waves is greatly reduced in these basins. The contrary would deny the established view that waves and their associated currents are the effective agents of basin planation.

The winds of the coast of Texas, on the average for the year, have as high a velocity as on any coast of North America, according to Weather Bureau data of wind strength. Therefore, we must seek a cause for the diminished effectiveness of the surface winds of these basins in activating waves in marine planation.

According to the writer's information, it is generally believed among students of waves that the length of the fetch in a closed basin is the factor which determines the amount of the full strength of the surface wind which is exerted in wave development (D. Johnson, 1919, pp. 22–24). This assumes a strong, relatively constant wind during the period of wave operation.

If the foregoing assumptions are correct, the depth of a basin, among those here studied—maximum depth not in a channel, or average depth of the basin floor, or other representative depth—is determined through marine planation by the wave base, which is itself determined by the average width of the basin, that is, its average fetch.

The converse of the foregoing proposition is also true, of course, that the depth of wave base is determined by the depth of the basin, but geologists must assume that, on this coast, the basins would be deeper if the waves had been strong enough in their scouring action to prevent the accumulation of incoming sediments. This is because the drowned valleys and initial coastal lagoons must have been considerably deeper than their present depths. We know that the entrenched valleys were originally 200–300 feet deep. The offshore bottom gradient on the coast today is far steeper than that in any bay or lagoon. The maximum basin depth of 16.5 feet is reached in the Gulf in less than a mile offshore. Also, the bottom sediments seem to be soft enough to permit erosion, because we find the larger embayments of drowned valleys to be wider than the original valleys. This is quite evident in Corpus Christi and Matagorda bays.

It seems evident that, where basins have been enlarged by marine planation, as in Corpus Christi Bay, the maximum observed depth of 16.5 feet is a true wave base of effective wave scour for this basin.

We may, then, summarize the argument of this section as indicating that (1) marine planation has occurred in the basins studied, (2) the representative basin depths are the local wave-base depths of marine planation for those basins, (3) the depth of planation is a function of (a) wave strength and depth, (b) of wind fetch and (c) of average basin width. Basins shallower than 3 feet have not been studied. It is not known whether these conclusions apply to very shallow basins.

Variation of equilibrium with climatic regime.—The climatic basis for the di-

vision of basins into two large groups for analysis has been discussed. Comparison of the graphs (Figs. 6 and 7) shows that where rainfall, runoff and silt load are greatest, and where streams commonly enter directly into the tidal basins, the latter are relatively shallow in comparison with the depths where the bays receive less inflow, precipitation, and alluvium. This seems to establish two equilibria of the internal basin forces. Humid climate seems here to be correlated with greater sedimentation, non-humid climate with deeper bottom scour.

It is not denied that other conditions may have influenced the differences in ratio found, such as diastrophism, but the evidence in hand is insufficient to assess this possibility. It would seem that crustal deformation has, on the whole, been slow enough for the interior forces to prevail in shaping the basins.

Diastrophism and dispersal patterns.—Where the pattern of dispersal of points in such graphs as Figures 6 and 7 is one of close clustering along the average curve, late, irregular crustal warping was probably at a minimum in the area of the existing basins. It might, however, have destroyed or recently created basins. The new basins would not be expected to fit the equilibrium curve until time had been allowed for their modification by normal interior forces.

Where such dispersal patterns may be found to be open with wide and irregular dispersal, and no small groups can be separated as having their own equilibria, it might be concluded that diastrophism had been active, with local irregularities. Irregularities of pattern might be caused by non-diastrophic exterior forces, but such activities would be revealed in the geomorphology of the region and the basin environs.

Occurrence of equilibria in tidal basins during post-glacial rise of sea-level.—It is not known how often or how continuously sedimentation of the entrenched stream valleys was able to balance the rise of sea-level closely enough to develop equilibrium conditions of basin form. If the maximum wave base of 16.5 feet now existing for the basins held then, or any such shallow figure, there must have been long periods when the water was too deep for equilibria to develop, as in the deeper waters of the Chesapeake to-day.

If there is an eustatic rise of sea-level of 10 centimeters (4 inches) per century and a regional tilt of 38 centimeters (15 inches) at Galveston, as Gutenberg (1941) concluded, or anything of this magnitude as Marmer (1943) would have us phrase it, then the equilibria of tidal basins has been able to operate in spite of it.

Equilibria during late coastal submergence.—In a study of the coast of Louisiana, Russell and Howe (1935, p. 499) conclude

> The entire Gulf Coast of the United States is a splendid exhibit of the consequences of active submergence. The mouth of practically every river is estuarine. . . . The subsidence . . . is so rapid that . . . only two rivers (north of Rio Grande) have been able to build deltas protruding into the Gulf. . . . Any comparatively short period of crustal stability would witness not only the rapid filling of their estuarine mouths but the growth of deltas into the Gulf as well.

They note that the last statement was recognized by many early writers.

For the coast of Texas, the specific data of subsidence are many, but so far none are in hand for considerable stretches separating points of evident submergence. Submergence of late date, possibly tilt, is noted at Galveston Bay, Nueces Bay, the shallow embayment of central Kenedy County, and for the Rio Grande delta front. Tilt may be indicated by a narrow zone along the front of the Brazos-Colorado delta.[17]

In spite of all this submergence, we find the condition of equilibrium of form in the tidal basins of Texas and Louisiana, a regional difference in equilibrium attributable with considerable plausibility to other than diastrophic differences, and such early soundings as we have for Texas basins indicating no significant change in bottom depths during the past 90–100 years in several and the past 250 years in one bay.

The only conclusion which seems to agree with the data and their reasonable interpretation for the coast of Texas is, that, if submergence has been general in recent centuries, it has been slow enough so that equilibrium of basin form has been maintained, and actual depths maintained in most bays for many decades past.

Alluviation caused by man.—In a condition of equilibrium of forces, the introduction of any new factor of significant value upsets the balance to a greater or less extent, with the development of a new equilibrium when the forces are again in static relation to each other. The only new factor known to have been introduced in recent centuries in this region, other than local diastrophic deformation, is man. His activities have greatly upset the former equilibrium in the plant and animal communities, resulting in a reduction of plant cover, in less stability of the soil, and in the bringing of additional amounts of alluvium either directly or indirectly into the tidal basins studied (Price and Gunter, 1943).

Civilized man first established settlements in force on the Texas coast after 1790, when the Spanish, under Escandon, colonized the south bank of the Rio Grande. These first Spanish settlements may have caused some vegetative depletion between Rio Grande and Nueces rivers before 1828–1831, but it was the coming of the Anglo-American settlers during and after that period and the development of the industrial revolution which produced the great cattle markets of 1870–1890 and over-stocking of cattle ranges, followed by serious damage to the native vegetation. It seems to have been mainly about 1870–1880 that acceleration of silting in Texas coastal streams began in earnest. This silting seems to be reflected in a general 0.5–3.0 foot shallowing of bottom recorded by the charts. Hence, the Coast Charts to 1872 are believed to represent, for recent centuries, the native condition of the tidewater basins. The 1890 editions also probably represent essentially native conditions.

The alluviation caused by man is further considered in the section on sedimentation.

[17] Conclusion of Frank G. Evans, Jr., from aerial photographs. Lecture before Corpus Christi Geological Society, 1939.

Maintenance of width:depth ratios in outer basins in late centuries.—From examination of the two maps of Matagorda and Lavaca bays made in 1689 and 1690 (Fig. 2, b, a), it seems that no appreciable shallowing of the embayment of the drowned valley of Lavaca River occurred in the 182 years previous to the date of the last shoreline survey here studied (1871), nor in the 244 years previous to the date of the latest soundings of the bay bottom (1934). In any case, scour and fill have been essentially in balance, with a late excess of scour. If the rate of sea-level rise calculated for Galveston held here, there may have been a fill of 3.9 feet between 1689 and 1934, although no change in depth. Such essential stability of ratios is believed to have been characteristic of at least the outer segments of the bays of Texas, although no complete survey of such scattered colonial records of tidewater soundings as may be in existence has been made by the writer and although a tendency to shallowing has developed since 1870.

Nueces River had been filled or nearly filled for 8 miles west of White Point by 1870, leaving only a few lakes and about 6 inches of water inland from the bay-head delta in the Nueces Valley. The contrast between the normally stable outer basin of this drowned embayed valley, Corpus Christi Bay, and its smaller, shallower inner segment or "settling basin," Nueces Bay, is to be seen not only in differences in shape but strikingly in the character of the bottom and the compaction of its sediments. Engineers report that when channel construction was begun in Corpus Christi Bay it had a hard clay bottom. Nueces Bay has a soft, water-soaked, silt bottom of considerable depth, it being possible to sound in this silt with poles and pipe without resistance. Lavaca and Navidad rivers have at some time in the Late Recent filled their valley for 10 miles below the head of a widened section which extends to the vicinity of Vanderbilt, Jackson County, and which seems to mark a former marine planation of the valley walls. In 63 years Trinity River advanced its bay-head delta, above sea-level, a mile southward into the Trinity Bay arm of Galveston Bay after it had isolated the upper end to form Turtle Bay. At the same rate it would have been 2.5 centuries ago when the delta finished filling an inner segment of the drowned valley and began its advance into Trinity Bay.

Segmentation promotes maintenance of ratios.—Segmentation by spits and bars seems to be a device by which the equilibrium ratio of width to depth is roughly maintained. This assumes that a basin which by some process has reached a condition of excessive width for its depth, or was being shallowed appreciably by alluvium, may be forced, by the inability of its shallow waves to handle all the sediments in motion, to deposit some of them above the general level of the bottom in the form of bars or spits where the waters are slack. Transportation of sediment along beaches builds spits and bars in places where the beach line curves so as to throw the sediment-laden current into deep water, where the current is checked.

Conditions of stability of form in alluviating basins.—From the foregoing considerations, it seems that the outer segments of most bays in drowned river val-

leys have remained and will remain relatively stable only so long as there are inner segments which act as settling basins. As soon as the inner segments are filled, the outer ones become the sites of alluviation under water. In most cases the advance of bay-head deltas and the alluvial plain follows shortly. Complete filling of the entrenched valley and the development of deltas at the Gulf shoreline follows the completion of this action.

Stability in non-alluviating basins.—In the basins of the types studied not receiving alluvium directly, such as in enclosed segments of the coastal lagoon, change of form occurs by (1) migration of tidal inlets, (2) shallowing of bottom and formation of washover fans (Fig. 4a) along the inner side of the off-shore bar during storm tides, (3) migration of dunes into lagoon, and (4) the growth and erosion of tidal deltas, spits and bars, as well as (5) crustal warping and (6) eustatic sea-level change. So far as this study goes, such basins tend to remain stable in ratio of width to depth until sudden, strong modifications of form occur.

Thus, the enclosed segments of the coastal lagoon studied and other non-alluviating basins may be affected without appreciable change by any of the factors of equilibrium previously mentioned, except the direct influx of large amounts of sediment. Basin form may, however, be permanently altered by the shifting of tidal inlets with consequent change in tidal deltas, and by the growth of washover fans.[18] Such events producing marked change in basin form are caused by the operation of forces not among those in equilibrium in the basins: the scour and deposition of tidal currents in tidal channels, and the work of storm tides overflowing the bar. The same statement is true of strong changes in sea-level due to crustal warping and eustatic sea-level movement.

Response of tidal basin to artificial changes.—In the history of engineering operations in Corpus Christi Bay we have an example of a degree of response of the basin to artificial changes in form and amount of sediment in suspension. A complete study of this history has not been made by the writer, but the facts presented are sufficient to indicate the type of response which has occurred.

When dredging is done in tidal inlets, the spoil may be thrown on the offshore bar above water, causing only a small part to find its way again into the bay by rain wash of the bare surface of the spoil material or by wind transportation. A certain amount of the bottom sediments, loosened in dredging, is not brought out of the water. When a boat channel or a deep-water ship channel is excavated across a bay, the spoil has in most cases been dumped on the bay bottom along the sides of the channel either in a continuous ridge or in a ridge with gaps. Here, some of the sediment does not settle into the spoil dumps but is carried off in suspension. Part probably slumps some distance under water off the sides of the fill.[19] The dredging of oyster reefs for "mud shell" for construction purposes visi-

[18] Described in section on sedimentation. Example of compensation for movement of tidal inlet of Aransas Bay by growth of a spit, so as to maintain equilibrium of form has been noted.

[19] Engineers engaged in ship-channel operations in this region state that the inner slopes of

bly makes the water muddy over considerable areas and loosens much sediment formerly stabilized in the reef.

The formation of a broken line of dump piles or of a continuous ridge of spoil across a bay seems to segment the bay effectively and to break up the wave formations and retard the movement of surface waters moving under the drive of the winds.

Aransas and Corpus Christi bays are large adjacent tidal basins, each with its own tidal inlet. Only about 1.0–1.5 feet of water connected them around a tidal delta in 1890. Corpus Christi Pass remained open, but no dredging was done by Federal bureaus. About 1912, a 12-foot boat channel was dredged from the Aransas Pass inlet into Corpus Christi Bay and across its north end to Corpus Christi (Figs. 2a, 3a). Corpus Christi Pass is said to have closed shortly after this. About 1925 this channel was deepened to 22.5 feet and since then to 27.5–30.0 feet. About 1942, a 30-foot branch of this channel was dredged southward through the middle of the bay to the Naval Air Training Station at Flour Bluff. Dredging in the bay for shell has gone on probably since fairly early days of the life of the town, but has been increased greatly since about 1927 with rapid growth of the city, including the coming of heavy chemical industries using shell in great quantities.

Information from local engineers indicates that shallowing of the bottom by about 2 feet was reported in the newspapers as occurring over some significant but now unknown area of the bay floor between 1905 and 1910.

Comparison of soundings of the bay as shown on charts published before and after the first deep-water channel was completed, shows shallowing (silting) over essentially the entire basin of 1–3 feet, exclusive of the spoil banks themselves. Comparison of the 1935 soundings with those of the 1943 edition of the Coast Charts, after the branch channel was dredged, shows a fairly extensive increase of the area of shallowing (silting), with a maximum of 4 feet.

When the three segments of Corpus Christi Bay created by the spoil banks of the two ship channels are measured and platted on the graph (14 d, e, f, Fig. 5), it is seen that they still have depths ranging from 4.75 to 7.25 feet greater than the average of the natural basins of the non-humid region for the new depths (Fig. 6).

It is, therefore, possible that silting will continue in these segments until 9.5 feet is the maximum depth instead of the original 16.5 of the chart of 1872. We may speculate whether such adjustment of form to artificial segmentation would occur as promptly if sediment were not being freed from the bottom by dredging.

---

the channels are about 3:1, the upper parts of the inner slope about 30:1, to 50:1, and the outer slopes about 5:1, or less, depending on the lithologic character of the spoil material. Where sand or other fluid material is being excavated, sticky clay is first placed at the foot of the slope to retain it. Thus, the slopes here designated are essentially maintained during construction, in their opinion.

If the bulk of the excavated material is actually contained within these slope dimensions, the change in bay depth caused directly by dredging and channel excavation is confined to the immediate vicinity of the spoil banks. However, strong muddying of the water while such operations are in progress, consistently observed, indicates that a significant volume of fines probably floats away to settle slowly in distant parts of the basin.

No age stages recognized in basin development.—In the former study of tidal-basin equilibrium (Price, 1933b) a larger number of points for Texas were platted on the graph than in the present study, including, in some cases, more than one ratio for a single long section or segment of a coastal lagoon. It was attempted to recognize age stages in the basins, with a tendency toward channel form on the one hand for "youth," and over-shallow basins on the other, for "old age." The present study does not present enough entries for either of the two climatic regions studied for us to recognize age stages, nor is the information as to former basin shape sufficient in any case for us to make a satisfactory study of historic changes in horizontal proportions.

SEDIMENTATION IN TIDAL BASINS FROM GEOMORPHIC POINT OF VIEW

Regional relations.—Some of the more obvious conditions of sedimentation may be reviewed from the information previously presented, although no special detailed studies of sedimentation have been made for this investigation. In order to present the foregoing from the viewpoint of sedimentation, a good deal of repetition is necessary, but in the process additional light is thrown on the preceding problems.

Sedimentation of the Recent plain and tidal waters of Texas and Louisiana is being carried on to-day in three main theaters of deposition, including areas above sea-level and others in shallow water: (1) deltas of the Gulf of Mexico; (2) coastal lagoons behind the offshore bars, (3) entrenched valleys.

In the history of this coast, the alluviation of the drowned entrenched valleys, within the region of the present shoreline and mainland tidewater zone, came first. When a valley was entirely filled to the mainland shoreline, a delta began to be formed in the Gulf, but not until then, the former deltaic activity at late Recent sea-levels having been of the bay-head variety. So soon as a delta protruded beyond the mainland shore, offshore bars were usually formed as spits projecting from each side—the lateral "wings" of the winged headland of shoreline treatises. Only five rivers have entirely filled their valleys in the area studied: Rio Grande, Colorado, Brazos, Mississippi, and Pearl.

On the central Texas coast, segmentation of—hence, much sedimentation in—the coastal lagoon caused by tidal deltas, bars and spits is most abundant between river deltas along the embayed part of the coast where tidal inlets are common—one to each large bay. At the northeast end of this embayed region, at Matagorda Bay, the first inlet lies some 45 miles southwest of the near edge of the large Brazos-Colorado delta, leaving the large western part of Matagorda Bay free of tidal deltas and hence of segmentation along the course of the lagoon. Segmentation does occur in drowned-valley branches of this bay.[20] At the south, at the Rio

[20] Artificial segmentation of the coastal lagoon portion of this bay occurred when the much choked lower part of Colorado River was dredged. The first floods washed much alluvium into the lagoon and steady growth of a bay-head delta has occurred, until the lagoon has been closed (Weeks, 1945, Figs. 12, 13, pp. 1711–14). An opening through the offshore bar was dredged for the river, which now enters the Gulf of Mexico and has begun to build a small delta there. These operations occurred between the years 1924 and 1936.

Grande delta, the inlet is now close to the mouth of the river. In each case, as in the intervening bays, the inlet is driven southward by the floods of the "northers."

A long section of the southern coast is free from inlets because, due to its aridity,[21] it is also free from inflowing rivers.

The causes for the separation of the active subdelta of Mississippi from its offshore bar, Chandeleur Islands, have not been investigated by the writer. Several geologists (Russell, 1936, p. 147) have thought that active subsidence caused the separation. Without the river to maintain a bar on the coast of western Louisiana and adjacent Texas, it has been destroyed or become static there and the coastal lagoon largely filled with marsh, adding a strip of Recent deposits.

Parts of Gulf deltas cut off from alluviation by the master stream during shifting of active subdeltas seem to have been subsiding and losing area to marine erosion more rapidly than they have been maintained by alluvium.

Segmentation has occurred in some deltaic basins, not in others. In drowned valleys, segmentation is most conspicuously developed where intermeander spurs or other projections of the walls fall opposite each other. Segmentation permits deposition in the form of spits, bars, and bottom deposits.

Sediments from embayed streams reach Gulf.—Studies of the sands of the offshore bar (Bullard, 1942) indicate that the rivers of the embayed coast discharge sediments into the Gulf through the bays and the passes, from the mouths of which they are distributed for great distances along the bar shore. The manner of this transportation has not been investigated. The writer once observed that, in a record flood of Nueces River between 1930 and 1940, brown flood waters discharged from Corpus Christi Bay through Aransas Pass into the Gulf. It seems that the level of the bay was sufficiently raised to flood communicating waters, a part reaching the Gulf through the inlet.

Sedimentation in coastal lagoon.—The facts in hand do not yield information on possible equilibrium of form in the long, non-segmented parts of the coastal lagoon. The long section south of Corpus Christi Bay lies in the semi-arid and dry-sub-humid regions and has been subjected in the past three-quarters of a century to heavy sedimentation by sand blown from an offshore bar segment, the vegetation of which was badly depleted and rendered desertic by overgrazing (Price and Gunter, 1943) and by saline floods of hurricanes. Rapid filling in one part of this section of the lagoon has been noted in the State Game, Fish and Oyster Commission Reports (1929–1930, pp. 55–57), but the area has been only imperfectly sounded and surveyed.

Sedimentation in the coastal lagoon may, in the total, have been large. This

[21] Douglas Johnson (1919, p. 373) attributed the location of tidal inlets remote from the mouths of deltaic streams to relative scarcity there of longshore sediment movement. However, the reasons for the distribution of inlets here is not so simple. The writer's study shows that there is one inlet for each major bay. There are kept open by outflow of stream floods from large bays and, particularly, by the high wind tides of the strong "northers" of winter. Hence, large size of a bay is essential to inlet persistence and inlets produce tidal deltas, which are a main cause of segmentation in the lagoon. The embayed coast necessarily lies between deltas, as deltas are embayment fillings.

would follow if we are to assume that the offshore bars were originally built up from a Gulf bottom with an offshore rate of deepening as great as that of to-day or if the modern offshore bars stand on a Gulf bottom which has been depressed to as steep an offshore gradient as that of the present Gulf bottom.

Normal sedimentation in much of the lagoon where it is enclosed and not affected by outside agencies, other than overflow of the bar, seems to be facilitated by growth of marine grasses and their retention of such sediments as are brought into basin areas containing stands of such grasses. A dense growth of grasses probably retards wave scour. Deposition of mud on lagoon bottom is said to promote the growth of marine grasses.[22] Such grasses are present in dense stands in Laguna Madre south of Corpus Christi Bay and probably in other sections. However, narrowing of the lagoon, other things being static, is most notably accomplished by the encroachment of washover fans.

Washover fans of offshore bar.—These features seem not to have been described for bars of the Gulf coast. Douglas Johnson (1919, pp. 305–06, Pl. 41) says:

> Large storm waves dash over the crest of the bar, and their waters flowing down the landward side build *wave deltas* into the edge of the lagoon.

The description would suit both large and small features. Johnson's illustration shows small lobes a few yards wide made of cobblestones washed over the coarse bar near Marblehead, Massachusetts. Lobeck (1939, p. 349) enlarges on this description somewhat in a paragraph on tidal deltas, and after describing that land form says:

> During storms, waves break over a low portion of a bar and carry material back into the lagoon, depositing *washovers*. Almost every bar bears on its lagoon side a row of deltas thus formed. This causes the crenulated margin of the lagoon side in contrast with the simple seaward shore.

Here the discussion links the two closely associated forms, tidal deltas and washovers, or washover deltas, which together produce the scalloped inner shorelines of the bars of the Texas coast.

Johnson's term wave delta seems to have priority, but suggests special origin by a wave. So far as the writer is aware it has not come into general use. The one example shown by Johnson is of tiny size. For such features, it may be useful. The term "washover" is less specific as to wave, or single wave, origin. The large washovers of the Gulf bars, though probably initiated by single great waves, may have been formed by a more general overflow. If we call them *washover fans*, the term seems to be fully descriptive.

Washover fans are characteristic of Padre, Mustang, and St. Joseph islands on the offshore bar of the coast of Texas. As they lie mainly below the 5-foot contour above sea, only an occasional element of washover fan sculpture is shown on

[22] A professional fisherman reported this occurrence in Red Fish Bay near Aransas Pass when a railroad embankment was built across it, segmenting it into two parts. See D. W. Johnson (1919), p. 380, and his reference to Shaler (1886, p. 364).

present topographic maps of the bar, but they are plainly visible from the air and on aerial photographs. The early editions of the Coast Charts show them in places by delicate patterns of terrain classification not used on modern editions. An example from St. Joseph Island west of Cedar Bayou is shown in Figure 4b. This mapping is photographic in its detail and is probably of considerable accuracy.

The washover fan is built out from the inner side of the high axis of the bar by flood tide waters which spill over it. The hurricane is the agent producing tides high enough to form washover deltas on this coast. Each fan has (1) a point of origin which is a depression in the summit of the bar, (2) a series of channels diverging fan-wise from the point of origin, and (3) low ridges and broad, low wedge-shaped elevations which lie between the channels. Some of the channels form narrow lagoons, lakes, or marsh strips and are commonly floored with finer particles than the ridges, some channels being of sticky sandy clay. The materials of the fans are derived by the flood waters from beach, bar, and dunes. While the fan is chiefly a depositional feature, it is partly erosional. It has points of similarity to a crevasse fan of deltaic streams and to the tidal delta.

The offshore bar of this section of the coast lies in the semi-arid and dry subhumid regions of Thornthwaite (Fig. 1a) and has a line of high sand dunes fairly well stabilized by grass which forms a wall just inland from the beach. These are the source-bordering lee dunes of Melton (1940, p. 122–23). This wall of dunes runs essentially parallel with the shoreline. The sandy plain inland from the beach-bordering dune wall contains extensive dune fields, some bare, some grassy. The common bare dune form is an asymmetrical barchan (Bagnold, 1940, Fig. 78e). Also present are longitudinal, seif, and barchan dunes, with Bagnold's (1940, pp. 191–92) sand drifts.

The washover fans, like the drifts, have their sources at gaps between dunes of the beach wall. The topography of the overflow fans, drifts, and dunes may become mixed. Other features which are found mixed with these elements of the low topography of the inner part of the bar are the concentric, encircling beach ridges of small islands to which the bar has locally retreated. Examples are shown in stipple on the preliminary prints of Padre Island and Brazos Santiago Island topographic sheets for Cameron County, Texas.

A log of an airplane flight at a height of 1,000 feet along Padre Island made the day after the hurricane of September 4, 1933, by T. W. Bailey, division engineer, State Highway Department, shows 17 "passes" and many "channels" through which water was pouring from the coastal lagoon to the Gulf (Reese, 1938, Ms. p. 60). A newspaper account listed 45 channels. The height of the tide was then estimated to be 4.5 feet, but it had been much higher during the storm. None of the new passes was cut to sea-level, or remained active after the water returned to normal conditions. Many dunes were reduced in height and their flanks smoothed to low slopes, others being destroyed, while most of the southern half of the island was denuded of its former cover of grasses (Price and Gunter, 1943, p. 145).

Burton Dunn of Corpus Christi, a Padre Island rancher, reports that the

cycle of hurricane flood, removal of vegetative cover, migration of dunes, and re-stabilization of dunes by grass has occurred several times at different places during the history of the island, covering, exposing, and re-covering old ranch landmarks. It is evident that the Gulf poured into the lagoon across the bar in considerable depth on September 4, carrying much sand, and that washover fans were then formed on the lagoon side of this bar, and old ones reshaped, where the current was concentrated between dunes at times when the tide was at appropriate heights. The return flow from the lagoon to the Gulf, observed by Bailey, must have further modified the fan topography especially in the gaps. Small fans were probably made on the Gulf side by this return flow, but these would be reworked or covered in a few years or months by beach activities.

Equilibrium through segmentation under increasing sedimentation.—In the present study, it has been found that there is a rough adherence of enclosed, oval tidal basins to a constant ratio of width to depth. This indicates that under natural conditions there has been (1) no significant change of form in outer basins since sea-level reached its present position, (2) slow adjustment of width and depth, or (3) where relatively rapid sedimentation has occurred, segmentation of shallowed basins has for a time delayed final filling by re-establishing equilibrium. Equilibrium can not be indefinitely maintained against a steady increase in the volume of materials available for sedimentation, or against rapid downwarping, but can only delay the processes of change.

The foregoing conclusions are reached from theoretical considerations of the width-depth ratios (Figs. 5–7) and observed conditions of segmentation. The writer has too few observations in hand of significant change of basin form in the natural state with accompanying information on precise depths below mean sea-level at significant dates to enable us to check all these conclusions at the present time.[23] We may, however, test them from events in the history of basins disturbed by large engineering operations.

Normal scour and fill.—Comparison of early and recent mapping and sounding in Texas bays little modified by man shows there has been a small amount of both scour and fill. Fill in several such bays seems to have reached about 1.5–2.0 feet and scour in parts of Matagorda Bay about 2 feet in 65 years. These slight changes seem to indicate the order of magnitude of the stability of bottom under natural conditions in these basins. Such changes, when not preponderantly in one direction, are insignificant in the total from a volumetric standpoint and are disregarded in this study. It is recognized that secular change in sea-level may have caused some of the recorded depth changes.

Shallowing of bottoms in basins disturbed by man.—In such basins as Corpus Christi and Galveston bays, where the whole area or virtually the entire area of bottom has been shallowed from 1 to 4 feet, from 6 to 40 per cent, since ship channels were dredged through them, it is evident that continuation of such engineer-

[23] It is possible that data in the files of the Coast and Geodetic Survey could be assembled for such a purpose.

ing works might lead to the extinction of large tidal basins and the formation of marshy flats with small lakes. In Galveston Bay, the distribution of sediments formed since the ship channel was dug to Houston seems to show that a significant part of the shallowing was caused by the settling of dredged silt, although the advance of Trinity delta under water was dominant.[24]

Significant trend of sedimentation indirectly caused by man.—It has been stated that, on the basis of the record, most of the tidal basins in Texas here studied have shallowed between 0.5 and 2.0 feet in their deeper parts or over significant bottom areas since the earlier charts of the coast of the period 1852–1871 were made. It seems safe to assume that silting is mainly responsible for this change in depth, because changes in basin outlines have not been extensive and changes in tidal heights in the inner waters should not have been greater than a few tenths of a foot.

As has been said, the volume of this apparent filling is probably small in comparison to the volumes of the bays. If it occurred in only half of the bays with approximately an equal amount of scour in the other half, it might be considered merely an incidental condition in the maintenance of essential equilibrium of form, or partly due to surveying errors. The actual conditions, however, indicate or strongly suggest a general tendency at present toward shallowing of the bays. This is in spite of such deepening of bays as would have occurred under the recent 14-inches-per-century rate of regional tilt of the Gulf Coast postulated by geophysicists (Gutenberg, 1941), provided it held throughout the mapping period.

When we look for some factor in the forces of equilibrium which may lately have been altered throughout the region or for some new factor, the only nondiastrophic change of this nature known is the coming of man, and the only force which he has altered generally in the region, to correspond with a general change in bottom depths of basins, is alluviation. It has been fairly well determined (Price and Gunter, 1943) that soil erosion by wind and water in recent decades has discharged eolian materials and alluvium into streams and tidal water bodies on this coast. It is, therefore, in order to consider that there is a trend on the Texas coast toward acceleration in the normal rate of filling of the more interior basin segments and a new trend toward shallowing of outer basins, including those in the coastal lagoon remote from river mouths. The writer has not critically investigated this situation in Louisiana.

Sedimentation accompanying estimated rise of sea-level in recent decades.—If sea-level has risen during the record period of fairly accurate tide observations discussed by Gutenberg (1941) and Marmer (1943, 1946), and if the rate of rise was about as calculated for Galveston (Gutenberg, 1941, Table 2) or 48 centimeters (19 inches) per century, then to the amounts of shallowing charted for this bay by the Coast and Geodetic Survey there may have to be added 1.5 foot to determine the amount of actual deposition.

[24] See Footnote 19.

If anything like a similar rate of sea-level rise has affected the other bays of Texas, then a considerable body of sediment may have been laid down in them during the colonial period. In the past 245 years of cartography for Matagorda Bay the amount there might have been of the order of 3–4 feet.

Such results would theoretically follow from the operation of the condition of dynamic equilibrium in tidal basins here studied. Search for submerged docks of the colonial settlements might yield methods of checking these suppositions.

Sedimentation in tidal basins from biological standpoint.—What to a geologist may be an incidental shallow scour and fill or only the beginning of a general sedimentation may involve considerable restriction and local extinction of biological communities, especially of the bottom-dwellers. In the bays of Texas, as in the tidewater areas of the Atlantic Coast of North America, there has been a gradual deterioration in the oyster industry for many decades. Biologists studying the causes of the extinction of oyster communities on reefs and the deterioration of those taken in commerce seem usually to attribute a part of this loss to silting. However, numerous other adverse factors are stressed by them. These include problems of management of the commercial cropping of oysters, including a lack of enforcement of a regular policy of replanting "seed" oysters, and lack of knowledge of the laws of oyster growth under the present adverse conditions. Also, the work of oyster parasites, industrial contamination of water, and such incidental items as the occasional closing of tidal inlets, floods of fresh water from rivers, and local damage to reefs resulting from engineering operations[25] are adverse conditions in oyster cultivation.

An example of the difference in viewpoint of the biologist studying the life of bottom-dwelling organisms and the geologist studying large-scale relationships in basin form may be had by comparing with the present conclusions a report of Paul S. Galtsoff (1941) on the oyster industry and problems of management of public reefs in Texas. Impressed by the volume of the incoming alluvium of Texas rivers, he states (Galtsoff, 1941, p. 1):

> The inshore waters of the Texas Coast, . . . are basins which receive *and deposit*[26] huge quantities of silt and other erosion products . . . .

and again (Galtsoff, 1941, p. 1):

> examination of the charts . . . (of the past 25 years) indicates . . . *profound*[27] changes in the depths of water and in the configuration of oyster reefs . . . .

Here, the tacit assumption is made that sediment coming into the bays and lagoons must be deposited there, without the author's inquiring whether it is

[25] The latter item includes the growth of the bay-head delta of Colorado River in the lagoonal end of Matagorda Bay after the river channel was dredged in 1926 (Weeks, 1945, pp. 1711–14). An oyster reef was covered by sediment because of these operations (Galtsoff, 1941, p. 1). Spoil banks of the Intracoastal Canal lately constructed are reported to have dammed Oyster Lake, near Trespalacios Bay, killing the oysters with fresh water.

[26] Italics by the present writer.

[27] Italics by the present writer.

equally deposited in the shallow, inshore segments where oysters of commercial type are not now taken and in the open basins where the commercial type are cropped, or what proportion of the sediments is discharged into the Gulf. An amount of silting which is insignificant or nearly insignificant from certain geological points of view may surely be "profound" from the standpoint of oyster culture. A layer of silt only a few tenths of a foot thick over areas of basin bottom several miles square, if it also covered reef flanks, would bring to an end the oyster fishing industry dependent on the reefs. A mere paper-thin layer is enough to prevent the setting of the spat or "seed oysters."[28] Such silting would be volumetrically insignificant when considered as a contribution to the filling of an entrenched valley of a major river.

The fresh-water floods which currently damage oysters on the reefs would probably not have been so numerous or so high if soil erosion and depletion of the vegetative cover had not been occurring in the inner parts of drainage basins under cultivation by the white man. Oyster communities weakened by the variety of adverse conditions now operative would be more susceptible to damage by parasites than under natural conditions.[29]

Galtsoff (1941, p. 1) remarks that occurrences of oysters buried in sediment at depths of 20 feet under the bays:

> show that the struggle of oysters against sedimentation has continued in local waters for many thousands of years and has not yet reached its final stage.

Oysters or "shells" have been reported down to 80 feet below sea at Copano Bay mouth (C. E. Johnson, 1940, profile, well No. 53). However, none of these deposits is likely to have been formed or covered when the Gulf was at its present level. The covering, then, did not occur in the present stage of equilibrium of tidal basins. The covering of most of these ancient oyster reefs must be attributed to the general post-glacial rise of sea-level, and the accompanying sedimentation.

SUMMARY AND CONCLUSIONS

1. The coast of the Gulf of Mexico in Louisiana and Texas contains in its unconsolidated sediments a great development of shallow bays, lagoons, lakes, and estuaries, located in drowned valleys, alluvial valleys, deltas, and the coastal lagoon.

2. Most of the tidal bodies of water are closed to the Gulf by bars or marshy plain but are connected with it through relatively narrow inlets (passes) or by long or short natural tidal channels.

3. Most of the more elongated tidal water bodies not of channel type have been segmented by spits, "reefs," bars, washover fans and tidal deltas into more or less oval basins which are saucer-shaped or broadly trough-shaped. Others

[28] These statements have been approved by marine biologists of the Game, Fish and Oyster Commission of Texas.

[29] This problem lies beyond the scope of this study.

are oval without segmentation. Data on the long, narrow laguna Madre were not available for this study.

4. While the regularity of oval shape varies widely, the dimensions of the 31 basins here considered to fall into this class range—in miles to feet—from 1 to 1, to 3.5 to 1, in length to width, and from 0.7 to 1, to 2.3 to 1, in maximum width to maximum depth.

5. By platting "average" width against maximum depth on rectangular axes, it is found that there is, for the basins of each of two climatic subdivisions of the coast, a rough, but definite and constant ratio of width to depth different in each subdivision which holds, in that subdivision, for all sizes of basins present in a straight-line relationship. "Average" width is determined from two dimensions: the maximum length of open water and the greatest open-water diameter roughly at 90° to this.

6. The maximum depth found in the oval tidal basins is 16.5 feet, which is the regional wave base of marine planation for the larger enclosed basins.

7. The conditions noted in 4, 5, and 6 indicate the existence of a condition of dynamic equilibrium between the normal forces operating in the basin which tend to produce scour or fill and thus to affect basin shape in one or more dimensions. This equilibrium exists in basins of a variety of origins, but all situated in unconsolidated sediments.

8. Basins of the humid region east of Brazos River receive large amounts of precipitation, most basins there having one or more entering streams which are presumed to bring significant amounts of alluvium into them.

9. The basins of the non-humid coast to the southwest receive less precipitation and less alluvium while losing more water by evaporation than those farther east. Most of the alluvium in the non-humid region is delivered into inner segments of the embayments of drowned valleys, the outer bays having relatively stabilized bottoms, except where artificial excavations have been made.

10. The basins of the humid region have greater maximum size but are proportionately shallower than those on the southwest. Most of those studied receive their alluvium directly.

11. Width-depth ratios of individual basins of the humid region platted in the graphs are dispersed in a straight-line relationship. The equation of the line is found to be (Fig. 7): $y=0.41x+3.0$, by using the statistical method of least squares, where y is in feet, x in miles. In equal units, the equation is:

$$y=2{,}164.8x+3.0.$$

12. Width-depth ratios of basins of the non-humid coast (Fig. 6) yield the average line: $y=x$, a ratio of 1:1 or, in equal units: 1:5,280. The variation in departure from these average ratios is less than ± 3 feet, or 30 per cent, and in most cases less than ± 2 feet.

13. All ratios given are approximate, precision not being feasible or significant. Relatively small variations in depths from period to period as recorded in

the Coast Charts are presumed to come mainly from irregular scour and fill of basin bottoms or from secular change in sea-level not due to local sedimentation, or both.

14. The data for the record period indicate, however, a slight shallowing (silting) of most of the enclosed basins of Texas—in spite of supposed rise of sea-level—but slight deepening (scour) of part of Matagorda Bay.

15. Tidal range for this coast is low, about 3.5 feet being the maximum normal displacement at the Gulf shoreline and high tide occurring ordinarily only once in a lunar day. In the bays the gravitational or "Gulf" tides are less, but appreciable. Imposed on these are wind tides which are thought to be commonly stronger in the inner parts of bays than the gravitational tides are there. Maximum shoreline changes—probably most of the significant change—are thought to occur during storm tides and storm floods. Hurricane tides of 4–15 feet are known in inner parts of bays, 20–25 feet at the Gulf shoreline.

16. The relative shallowness of basins of the humid coast is thought to have been caused by more alluvium entering them than the non-humid basins, producing a difference in the conditions of equilibrium in the two regions, with greater bottom-silting on the humid coast.

17. It seems, on the basis of incomplete study, that fewer oval basins of Louisiana are segmented by bars and spits than in Texas. This may be due in part to differences in origin of the depressions.

18. The marked tendency of elongated lagoons and embayments of the non-humid coast in Texas to segment—although made possible by local conditions—is thought to show a method of maintaining an equilibrium between scour and fill where more sediment is being handled than can be removed from the basin (1) the change in basin size being accomplished *by change in outline* by segmentation, bar growth taking place in slack waters where the waves are not able to move all the sediment, or (2) where segmentation is the prior or controlling event and process, the *change may be chiefly in depth*, silting of basin floors occurring.

19. Segmentation tends to occur where obstructions narrow the elongate lagoon or basin. Such obstructions include (1) intermeander spurs of drowned valleys, (2) tidal and stream deltas and (3) washover fans of offshore bars. Spits build out from obstructions and become connected across the bays by bars. Oysters grow on some submerged bars, forming reefs and tending to stabilize the bar. Widely scattered over some bays, these shells retard bottom scour.

20. Prograding of some basins by festoons of beach ridges and spits formed along the shores in shallow water may be a response of the basin under equilibrium to weak waves and relatively abundant coarse sediment, shrinkage occurring in horizontal dimensions.

21. Outside forces may be exerted which more or less suddenly change basin shapes, as where floods form washover fans in coastal lagoons, a radical change occurs in the position of a river mouth, or crustal deformation takes place.

22. After or during the course of these changes induced by exterior non-basin

forces, it is believed that the normal interior basin forces tend to restore them or their remnants to forms and dimensions which conform to the width-depth ratio for their region. The dynamic equilibrium recognized holds for the long-term average conditions, but in any year or short period of years may be upset. In some cases, short-term changes may be overcome and an equilibrium restored which permits existence of a tidal basin, or basins, in other cases not, as when a basin becomes completely filled by washover fans and tidal deltas.

23. It is evident that the fetch, or distance of translation of wave motion and of its causative agency the surface wind, is directly proportional to wave depth and determines the depth of effective wave scour. This wave-and-wind fetch is the width of the open part of the basin.

24. It is supposed that long continued slow change in any factor affecting basin shape, whether among those normal to the basin or outside factors, would permit maintenance of the characteristic regional equilibrium form and ratio.

25. Examples of appreciable change of shape in the basins of the Texas coast, during the record period of chart-making, other than those discussed in relation to depth, have not come to hand. The Louisiana coast has not been studied as to the effect of such change on basin shape there.

26. Dredging of ship channels with the building of flanking spoil banks has artificially segmented Corpus Christi Bay, producing a degree of silting in each segment—a response to reduction in size which is in the expected direction for the maintenance of equilibrium shape. How rapidly this silting might have occurred if loose sediment had not been freed in the bay by dredging is not known.

27. In all these considerations there are omitted the action of tidal currents and the forms of tidal channels either separately or as parts of basins. The action of such currents, so far as they are confined to channels and channel scour, are not subject to the equilibrium of forces which controls basin shape.

28. The general conditions of sedimentation observed in the study are reviewed, but no detailed investigation has been made of the progress of sedimentation revealed by successive chart editions. Data in the files of the Coast and Geodetic Survey may be adequate for such a study.

29. The viewpoint of this study toward basin form is that of the gross changes appreciably affecting the width-depth ratios. A condition of relative stability of form, from this viewpoint, would include "minor" changes which might be "profound" when viewed by the student of small marine organisms which live on the bottom and on reefs, such as the oyster.

30. Deterioration in oyster farming along Gulf and Atlantic coasts for several decades past is attributed by marine biologists to a variety of unfavorable conditions and factors, including silting of bottoms and reef surfaces, and the incidence of floods of fresh water.

31. Some of these adverse conditions have been accelerated by man's activities, including major engineering operations in the affected waters and acceleration of soil erosion due to cultivation and grazing.

32. The addition or aggravation of such unfavorable conditions brought about by man again reacts upon the oyster unfavorably by weakening it and its communities and making it and them more vulnerable to other unfavorable living conditions.

REFERENCES CITED

BAGNOLD, R. A. (1941), *The Physics of Blown Sand and Desert Dunes*. xx, 265 pp. Methuen and Company, London.

BOLTON, H. E. (1915), "The Location of La Salle's Colony on the Gulf of Mexico," *Mississippi Valley Hist. Rev.*, Vol. 2, No. 2 (September), pp. 165–82, map opp. p. 173.

——— (1924), The same, *Southwestern Hist. Quar.*, Vol. 27, No. 3 (January), pp. 171–89, map on p. 180.

BULLARD, F. M. (1942), "Source of Beach and River Sands on Gulf Coast of Texas," *Bull. Geol. Soc. America*, Vol. 53, No. 7 (July), pp. 1021–43.

DOERING, JOHN (1935), "Post-Fleming Surface Formations of Coastal Southeast Texas and South Louisiana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 5 (May), pp. 651–88.

FARIS, O. A. (1933), "The Silt Load of Texas Streams," *U. S. Dept. Agriculture Tech. Bull. 382*. 71 pp.

FISK, H. N. (1944), "Geological Investigation of the Alluvial Valley of the Lower Mississippi River," *Mississippi River Comm., War Dept., Corps of Engineers, U. S. Army* (December 1). 78 pp.

FLEMING, R. H. See Sverdrup.

GALTSOFF, P. S. (1941), "Oyster Industry and Problems of Management of Public Oyster Reefs in Texas," (*Texas*) *Game Fish and Oyster Commission, Coastal Division*, Corpus Christi (April 10, mimeographed report). 6 pp.

GUNTER, GORDON, See Price, 1943.

GUTENBERG, BENO (1941), "Changes in Sea-Level, Post-glacial Uplift, and Mobility of the Earth's Interior," *Bull. Geol. Soc. America*, Vol. 52 No. 5 (May), pp. 721–72.

HACK, J. T. (1941), "Dunes of the Western Navajo Country," *Geogr. Rev.*, Vol. 31, No. 2, pp. 240–63.

HACKETT, C. W. (1931), *Pichardo's Treatise on the "Limits of Louisiana and Texas,"* Vol. I. 630 pp. Univ. Texas. (Vol. II published 1934. 618 pp.).

HAGGARD, J. V. (1941), *Handbook for Translators of Spanish Historical Documents*. 72 pp. Oklahoma City, Semco Color Press.

HOWE, See Russell, 1935.

HUSON, HOBART (1935), *El Copano; Ancient Port of Bexar and La Bahia*. 64 pp. San Antonio, privately published.

JOHNSON, C. E. (1940), "Aransas County, Texas; Records of Wells, Driller's Logs, Water Analyses, Cross-Sections, and Map Showing Locations of Wells," (*U. S.*) *Work Projects Administration, Projects 10448 and 10443*. 45 pp.

JOHNSON, DOUGLAS N. (1919), *Shore Processes and Shoreline Development*. xvii, 584 pp. John Wiley and Sons, New York.

JOHNSON, M. W. See Sverdrup.

KENNEDY, WILLIAM (1841), *Texas: the Rise, Progress and Prospects of the Republic of Texas*. xlviii, 939 pp., maps. London. Reprinted by the Molyneaux Craftsmen, Inc., Fort Worth, Texas (1925).

MARMER, H. A. (1943), "Tide Observations at Baltimore and the Problem of Coastal Stability," *Geogr. Rev.*, Vol. 33, No. 4 (October), pp. 620–29.

——— (1946), "The Use of Mean Sea Level as a Geophysical Datum," *Trans. Amer. Geophys. Union*, Vol. 27, No. 5 (October), pp. 682–84.

MELTON, F. A. (1940), "A Tentative Classification of Sand Dunes, Its Application to Dune History in the Southern High Plains," *Jour. Geol.*, Vol. 48, No. 2 (February-March), pp. 113–74.

PRICE, W. ARMSTRONG (1933a), "Reynosa Problem of South Texas, and Origin of Caliche," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 5 (May), pp. 488–522. Also in *Gulf Coast Oil Fields*, Amer. Assoc. Petrol. Geol. (1936), pp. 550–87.

——— (1933b), "Role of Diastrophism in Topography of Corpus Christi Area, South Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 8 (August), pp. 907–62; slightly revised in *Gulf Coast Oil Fields*, Amer. Assoc. Petrol. Geol. (1936), pp. 205–50.

——— (1936), "Hurricanes, Deltas and Resacas," *Proc. and Trans. Texas Acad. Sci.*, Vol. 19 (*Trans.* 1934–1935), (abstract), pp. 30, 31.

——— (1939), "Physiographic Mapping of Quaternary Formations in Rio Grande Delta" (abstract), *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 12 (December), pp. 1875–76.

———, AND GUNTER, GORDON (1943), "Certain Recent Geological and Biological Changes in South

Texas, with Consideration of Probable Causes," *Proc. and Trans. Texas Acad. Sci. for 1942*, Vol. 26 (*Trans.*), pp. 138–56.

RAISZ, ERWIN (1934), "Rounded Lakes and Lagoons of the Coastal Plains of Massachusetts," *Jour. Geol.*, Vol. 42, No. 8 (November-December), pp. 839–48.

REESE, PAULINE (1938), "The History of Padre Island" (Texas), *manuscript thesis* for M.A. degree, Texas College of Arts and Industries, Kingsville, Texas. 125 pp.

RUSSELL, R. J. (1936), "Physiography of Lower Mississippi River Delta" in "Lower Mississippi River Delta," *Louisiana Geol. Survey Bull. 8*, pp. 1–193.

——— (1940), "Quaternary History of Louisiana," *Bull. Geol. Soc. America*, Vol. 51, No. 8 (August), pp. 1199–1234.

———, AND HOWE, H. V. (1935), "Cheniers of Southwestern Louisiana," *Geogr. Rev.*, Vol. 25, No. 3 (July), pp. 449–61.

SHALER, N. S. (1886), "Sea Coast Swamps of the Eastern United States," *U. S. Geol. Survey 6th Ann Rept. for 1885*, pp. 353–98.

STATE GAME, FISH AND OYSTER COMMISSION (Texas) (1930), *Year Book on Conservation of Wild Life, 1929–1930*, Austin, Texas; pp. 54–58: "A Sail Down the Laguna," by J. G. Burr and others.

SVERDRUP, H. U., JOHNSON, M. W., AND FLEMING, R. H. (1942), *The Oceans, Their Physics, Chemistry and General Biology*. x, 1087 pp. New York, Prentice-Hall, Inc.

THORNTHWAITE, C. W. (1931), "The Climates of North America According to a New Classification," *Geogr. Rev.*, Vol. 21, No. 4 (October), pp. 633–55.

——— (1941) "Atlas of Climatic Types in U. S. 1900–1939." *U. S. Soil Conserv. Service, Dept. Agr. Misc. Pub. 421*, p. 3.

VISHER, S. S. (1946), "Climatic Maps of Geologic Interest," *Bull. Geol. Soc. America*, Vol. 56, No. 7 (July), pp. 713–36.

WEEKS, A. W. (1945), "Quaternary Deposits of Texas Coastal Plain between Brazos River and Rio Grande," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 29, No. 12 (December), pp. 1693–1720.

WEST, E. H. (1905), "De Leon's Expedition of 1689; An Annotated Translation," *Quarterly Texas State Hist. Assoc.*, Vol. 8, No. 3 (January), pp. 199–224, map frontis.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 31, NO. 9 (SEPTEMBER, 1947), PP. 1664-1677, 4 FIGS.

GEOLOGICAL NOTES

REVISED CORRELATION OF JURASSIC FORMATIONS OF PARTS OF UTAH, ARIZONA, NEW MEXICO, AND COLORADO[1]

A. A. BAKER, C. H. DANE, AND J. B. REESIDE, JR.[2]
Washington, D. C.

A summary of existing knowledge of the correlation of the Jurassic rocks of considerable parts of Utah, Arizona, New Mexico, and Colorado was published by the writers in 1936.[3] This summary was based on detailed mapping by several parties of the Geological Survey in southeastern Utah, supplemented by extensive reconnaissance examination by the writers in adjoining regions. The proposed correlations recognized the general equivalence of the Todilto limestone of northwestern New Mexico and northeastern Arizona with the "middle La Plata" of the San Juan Mountain region of southwestern Colorado, and the equivalence of the Entrada sandstone as defined and widely mapped in eastern Utah with the "lower La Plata" sandstone of the San Juan Mountains. They recognized further that the bedded sandstone and shale between the Navajo sandstone and the Wingate sandstone of the Utah area was an older unit than the Todilto, with which it had previously been correlated.

Continuing geologic studies in the general region in the ensuing decade have suggested several modifications in the correlations proposed in 1936 by the writers. For example, detailed work in western Colorado by Fischer and others[4] shows that the Summerville formation extends into that area as a traceable lithologic unit and is equivalent at least in part to the Wanakah formation. The Navajo sandstone also has been extended farther east than originally supposed. The Entrada sandstone of western Colorado has been recognized to extend into the area east of the Front Range and a considerable volume of evidence has been adduced[5] that indicates that the Entrada extends into northeastern New Mexico, where it is the Jurassic sandstone that was designated by the writers and others as the Wingate sandstone.

[1] Manuscript received, May 19, 1947. Published by permission of the director of the United States Geological Survey.

[2] Geologists, United States Geological Survey.

[3] A. A. Baker, C. H. Dane, and J. B. Reeside, Jr., "Correlation of the Jurassic Formations of Parts of Utah, Arizona, New Mexico, and Colorado," *U. S. Geol. Survey Prof. Paper 183* (1936).

[4] R. P. Fischer, "Vanadium Deposits of Colorado and Utah," *U. S. Geol. Survey Bull. 936-P* (1942), and unpublished data.

Marcus I. Goldman and A. C. Spencer, "Correlation of Cross' La Plata Sandstone, Southwestern Colorado," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, No. 9 (September, 1941), pp. 1745–67.

[5] R. L. Heaton, "Contribution to Jurassic Stratigraphy of Rocky Mountain Region," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 8 (August, 1939).

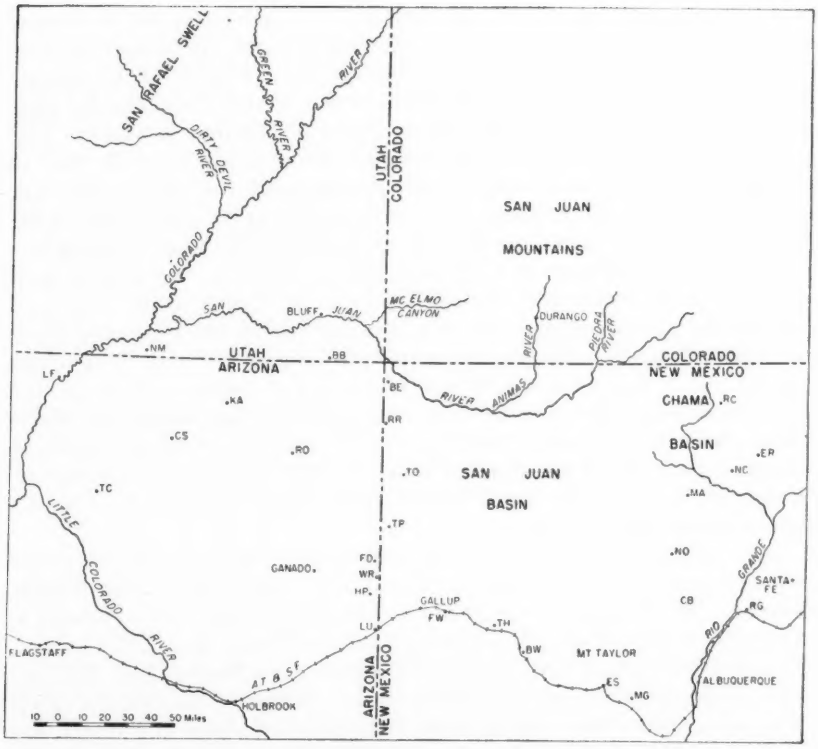


FIG. 1.—Index map showing localities.—BB, Boundary Butte; BE, Beclabito; BW, Bluewater; CB, Cuchillo Blanco; CS, Cow Springs; ER, El Rito; ES, El Rito Siding; FD, Fort Defiance; FW, Fort Wingate; HP, Hunters Point; KA, Kayenta; LF, Lees Ferry; LU, Lupton; MA, Mesa Alta; MG, Mesa Gigante; NC, Navajo Canyon; NM, Navajo Mountain; NO, Nacimiento Mountains; RC, Rio Canones; RG, Rio Galisteo; RO, Rough Rock; RR, Red Rock; TC, Tuba City; TH, Thoreau; TO, Toadlena; TP, Todilto Park; WR, Window Rock.

For some years, therefore, there has been a suggestion that much of the Jurassic sandstone in northeastern New Mexico is equivalent to the Entrada sandstone of the Animas River area at Durango, Colorado, and the Piedra River area somewhat farther east, rather than to the lower part of the Glen Canyon group, as the writers supposed in 1936. The writers' interpretation as shown on Figure 3 of their paper required the termination of the Entrada sandstone southward under the Chama Basin, New Mexico, and also a termination of the Wingate sandstone of New Mexico northward from exposures in the Chama Basin and the Nacimiento Mountains region (NO, Fig. 1). In fact, the Jurassic sandstone of the Chama Basin seemed surely to be equivalent to the sandstone farther east in New Mexico, for which an assignment to the Entrada was indicated, and

neither lithologic characteristics nor stratigraphic position precluded its correlation with the Entrada sandstone of the Piedra River area. An attempt to solve this stratigraphic problem was made by Heaton,[6] who concluded that the lighter-colored Entrada sandstone of Chama Basin thinned westward and that the deep red sandstone at the type locality of the Wingate sandstone in western New Mexico thinned eastward and northeastward. Later work by Charles B. Read of the Geological Survey and his associates in northwestern New Mexico led them to the contrary conclusion, namely, that the sandstone at the type locality of the Wingate and the sandstone over all of northeastern New Mexico are to all appearances the same sandstone. In 1946 the writers undertook a review of the field evidence for the correlations. In the latter part of August, C. H. Dane and J. B. Reeside, Jr., accompanied by C. B. Read and Ralph Imlay, revisited many of the critical sections especially in southwestern Colorado and northwestern New Mexico, and in the first half of November, 1946, A. A. Baker, C. B. Read, and P. V. McKee examined other sections in northwestern New Mexico and northeastern Arizona. As a result of the new evidence obtained, some revision of the present writers' earlier opinions regarding the Jurassic correlations is required. A summary of conclusions is submitted here in advance of the preparation of a more comprehensive discussion.

The Entrada sandstone, with more or less typical lithologic character and in normal sequence with the underlying thin Carmel formation, and the Navajo, Kayenta, and Wingate formations of the Glen Canyon group are recognized at Navajo Mountain, Utah (NM); Kayenta (KA) and Rough Rock (RO), Arizona; Boundary Butte, Utah (BB); and Beclabito dome, New Mexico (BE). The overlying Todilto limestone has not been recognized at Navajo Mountain, is absent at Boundary Butte, but crops out with characteristic lithology at Kayenta, Red Rock, Ariz. (RR), and Beclabito dome. Southward from Red Rock, the Todilto limestone is present at Toadlena (TO) and at its type locality at Todilto Park (TP). The underlying Entrada sandstone thickens southward from Red Rock to Toadlena and to Todilto Park, where it is the thick cliff-forming sandstone which all previous workers, including the writers, have correlated with the Wingate sandstone of the Fort Wingate region. This cliff-forming sandstone which crops out along the Arizona-New Mexico State line at Todilto Park, Window Rock (WR), Hunters Point (HP), and Lupton (LU), and in the cliffs north of Fort Wingate, New Mexico (FW) is thus equivalent to the sandstone that is called Entrada over most of Utah and Colorado, and has below it a thin zone of red silty sand and shale that is considered to be equivalent to the Carmel formation. Eastward from Fort Wingate this sandstone and associated strata crop out more or less continuously along the Santa Fe Railroad on the southern margin of the San Juan Basin and sections were measured at Thoreau (TH), Bluewater (BW), El Rito Siding (ES), and Mesa Gigante (MG). Scattered intermittent exposures along

[6] R. L. Heaton, *op. cit.*

the east side of the San Juan Basin as at Cuchillo Blanco (CB), Nacimiento Mts. (NO), and Rio Galisteo (RG) offer convincing evidence that the sandstone extends northward to the Chama Basin and is the same sandstone that crops out at Mesa Alta (MA), Navajo Canyon (NC), El Rito (ER), and Rio Canones (RC) in the Chama Basin. The writers are, therefore, in agreement with C. B. Read and his associates that the Jurassic sandstone at the type locality of the Wingate (FW), at several localities in the Chama Basin, and farther eastward in New Mexico are the same and are equivalent to the Entrada sandstone.

The Glen Canyon group, composed, in descending order, of the Navajo sandstone, Kayenta formation, and Wingate sandstone, with more or less typical lithologic character, is recognized at Rough Rock (RO), Boundary Butte (BB), and Beclabito dome (BE). The Navajo is 220–230 feet thick and the Kayenta is 6–44 feet thick. The complete thickness of the Wingate was determined only at Rough Rock where it is 308 feet thick. Southward from Beclabito dome the Navajo sandstone is scarcely differentiable from the lower part of the Glen Canyon group, and the Kayenta is not recognizable. At Toadlena (TO) the Glen Canyon group is 425 feet thick, and is represented by a series of pinkish buff to reddish brown sandstone beds with interbedded soft silty red sandstone. Between Todilto Park (TP) and Lupton (LU), the Glen Canyon is 175 to 300 feet thick, and is represented by silty buff to orange-brown sandstone that crops out locally in prominent cross-bedded ledges and in slopes below the cliffs formed by the overlying sandstone that is now correlated with the Entrada. This relatively soft reddish sandstone unit hitherto included in the Chinle formation is readily differentiated from the underlying red to purplish red conglomeratic beds of the Chinle. It is recognized in the Fort Wingate area (FW) of New Mexico, and probably extends much farther eastward in New Mexico. Whether the Navajo sandstone grades laterally into beds in the upper part of this soft sandstone unit in the southern outcrops, or whether it wedges out southward and thus leaves the Wingate sandstone as the only representative of the Glen Canyon group in this unit, is uncertain. Some evidence was observed to indicate that this silty phase of the Glen Canyon may grade laterally into rocks of Chinle lithology.

Obviously, these new conclusions as to correlation pose a problem in stratigraphic nomenclature. A strict application of the principles of priority would require that the name Wingate sandstone be now applied to the stratigraphic unit heretofore called Entrada, and would also require that a new name be applied to the Wingate sandstone of Utah and adjacent regions. In current usage for the Colorado Plateau and surrounding areas, these names apply to distinctive and widespread formations. Through use in numerous publications, they are firmly entrenched in geologic literature and are well known to many geologists. In the opinion of the writers, the abandonment of this nomenclature through the application of the principles of priority would be unfortunate and confusing. Accordingly, the name Entrada sandstone is extended to include the sandstone at the type locality of the Wingate sandstone, and the name Wingate is retained for the

sandstone forming the lower part of the Glen Canyon group, with the understanding that the original type locality of the Wingate has been abandoned. For the present, the name Glen Canyon group is extended to include the undivided equivalents of the Navajo sandstone, Kayenta formation, and Wingate sandstone that crop out below the Entrada sandstone and above the Chinle formation in parts of New Mexico and Arizona.

The Todilto limestone unit, which the writers earlier regarded as a basal phase of the Morrison formation, was observed at places during their latest field examination to be unquestionably transitional downward into the Entrada sandstone, and at many localities to be overlain on an erosional unconformity by clastic beds of the Morrison formation. From the Todilto, fish of marine affiliations have been collected at several localities. The sum total of this evidence, particularly when combined with the suggestions of several authors that the Summerville formation is more widespread to the east than formerly supposed, seems to indicate that the Todilto should be regarded as representative of the Curtis or perhaps the Summerville formation. The Todilto had been previously recognized by us as extending northward to Beclabito Dome (BE). It has not been observed at Boundary Butte (BB), but has now been recognized at Kayenta (KA), Cow Springs (CS), and Tuba City (TC), Arizona, and other localities. Its geographic extent is thus considerably greater than had been previously recognized, and its area of outcrop above the Entrada sandstone extends northward into the area beneath which the thinning edge of the Kayenta formation dies out between the merging sandstone of the Navajo and Wingate. It now appears reasonable to exclude from the Morrison formation the Todilto limestone and likewise the gypsum as being probably an evaporite related to the withdrawal of the Upper Jurassic sea. The beds closely related to the Todilto include some shale and sandstone locally underlying the limestone and in places above it. Inasmuch as the upper limit of the beds that may properly be assignable to the San Rafael group, rather than to the Morrison formation, is not yet definitely known in New Mexico, it seems desirable to extend into New Mexico and adjacent parts of northeastern Arizona, for these upper beds of the San Rafael group, the use of the term Wanakah formation, which has been sharply discriminated from the overlying Morrison in the San Juan Mountain region of southwestern Colorado. The Todilto limestone and gypsum where present are thus members of the Wanakah formation.

The massive sandstone above the Entrada at Todilto Park (TP), at Navajo Church near Fort Wingate, at Lupton, and elsewhere in northern Arizona seems most probably to be a facies of the Morrison formation. Southward from Todilto Park (TP), the Todilto thins out and the massive sandstone rests directly on the Entrada from Window Rock (WR), to Lupton (LU), where a contact between these sandstones, which have very similar lithologic characters, is recognizable with difficulty.

CLASSIFICATION OF FAULTS[1]

MASON L. HILL[2]
Bakersfield, California

Confusion in fault nomenclature existed before the classifications of Reid,[3] Gill[4] and Clark[5] and it still exists. Leith[6] said ". . . it is clear that the accurate naming and classification of faults present an exceedingly complex problem which has not yet been solved."

Reid, Gill and most workers classify faults on the basis of the orientation of the displacement, the *net-slip*. Clark and some others classify faults according to inferred genesis; for example, *tensional*. Others[7] classify by relationship to associated structural features; for example, *transverse* fault or by the relationship of faults to each other; for example, *radial* faults. The classification proposed herein is based mainly on apparent orientation of displacement, the *separation(s)*.

Separation[8] is apparent relative displacement measured in section, plan or as otherwise desired (only *dip* and/or *strike-separations*, A and B of the accompanying diagram, are used in this classification). It is a critical aspect of faulting which is commonly determined and thus offers a practical and significant basis of classification.

Slip[9] is actual relative displacement and since many orientations of *net-slip* are usually possible for an observed *separation* it does not furnish a practical basis for classification (1 through 5 of diagram). Genesis of faults, the character and orientation of the causal stresses, does not offer a practical means of classification because faults do not obviously fall into separate categories due to obviously different origins. The relations of faults to other structures (as transverse), or to other faults (as fault patterns), do not give significant classifications because such classifications are not based on the characteristics of the faults themselves.

The classification of faults proposed here is as follows.

NORMAL (in vertical section, hanging wall is relatively and *apparently* down—including vertical faults)

REVERSE (in vertical section, hanging wall is relatively and *apparently* up—restricted to faults which dip more than 45°)

RIGHT LATERAL (in horizontal section, side opposite observer is relatively and *apparently* to the right)

[1] Manuscript received, June 6, 1947.

[2] Richfield Oil Corporation.

[3] H. F. Reid *et al.*, "Report on Nomenclature of Faults," *Bull. Geol. Soc. America*, Vol. 24 (1913), pp. 163–86.

[4] J. E. Gill, "Fault Nomenclature," *Trans. Roy. Soc. Canada*, 3d Ser., Vol. 35 (1941), Sec. IV, pp. 71–85.

[5] Stuart K. Clark, "Classification of Faults," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27 (1943), pp. 1245–65.

[6] C. K. Leith, *Structural Geology*, p. 69. Henry Holt (1923).

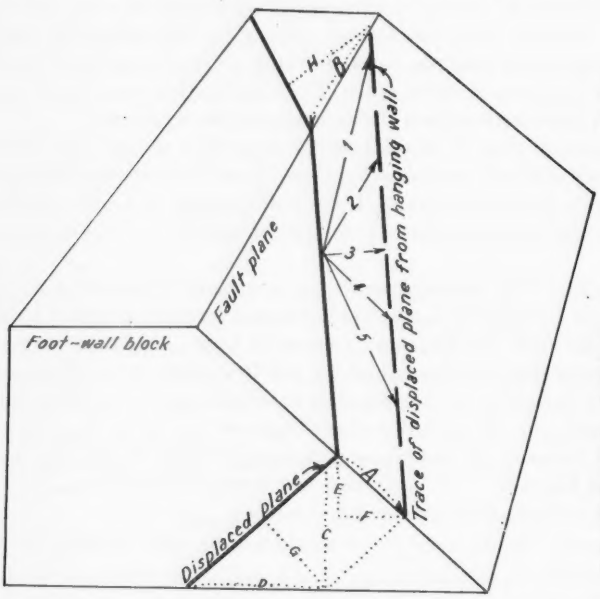
[7] See current text books on structural geology, especially, *Structural Geology* by Marland P. Billings, Prentice-Hall, 2d printing (1946).

[8] Reid, *op. cit.*, p. 169.

[9] Reid, *op. cit.*, p. 168.

LEFT LATERAL (in horizontal section, side opposite observer is relatively and *apparently* to the left)
THRUST (any fault which dips less than 45° and evidences *dip-separation* and horizontal shortening)
RIGHT (or LEFT) LATERAL NORMAL
RIGHT (or LEFT) LATERAL REVERSE
RIGHT (or LEFT) LATERAL THRUST
(combinations of the types above and should be used when both *strike* and *dip-separations* are known—see diagram of *left lateral normal fault*)

After a fault is classified according to the foregoing terminology, any desired *separations* (A through G of diagram), the relationships of the fault to associated



The strike-separation is B, the dip-separation is A. Other separations are:
C Vertical-
D Horizontal- (in dip plane)
E Vertical component of dip-
F Horizontal component of dip-
G Stratigraphic or perpendicular-
H Normal horizontal-
Only the dip-separation (A) and the strike-separation (B) are used to classify a fault.

Some possible net-slips are shown by 1 through 5. Notice that (1) has a relative upward component of the hanging wall and that (5) has a right lateral component of actual relative displacement.

Diagram of left lateral normal fault, showing *separations* and *slips*

structures, and other pertinent data may be described and discussed. If information on the orientation of the *net-slip* is available, it should be adequately described.

The critical aspect of the proposed classification is that the fault name designates apparent displacement as shown by *dip-separation* and/or *strike-separation* (A and B of diagram). Thus an objective and often a three dimensional concept of the fault is denoted in the name. The difference between *separation* and *slip* is well known, but although Reid[10] defines these terms and even points out that

[10] Reid, *op. cit*, p. 177.

slip is seldom determined, he nevertheless defines "normal faults, where the hanging wall has been depressed relative to the footwall." Though others specify apparent displacement in their definitions[11] it is surely common practice to consider the terms, *normal* and *reverse*, to indicate actual relative movement. Actual relative displacement is, of course, important but for the purpose of classification the *slip* is too rarely ascertained. If *net-slip* is available it should be described but even if, as in case 1 and case 5 of the diagram, the actual relative movement has components which are the opposite of the *separations*, the classification of the fault should not be changed.

The term *normal* as used here is applied to those faults, including the vertical case, which have an *apparent* and relative *dip-slip* of the hanging wall down the fault plane. The reason for including the vertical fault here is that the limiting case between *normal* and *reverse* faults does not deserve a special name since truly vertical faults, and particularly those showing *dip-separation*, are relatively uncommon. Furthermore, a term for this limiting case between *normal* and *reverse* types might be used when closer observation would allow either *normal* or *reverse* to be used.

Present usage of the term *reverse* is inconsistent because it is often used synonymously with *thrust*, or *thrust* is considered a sub-class of *reverse*, or *reverse* and *thrust* are employed to distinguish between separate types of faulting. More consistent usage is desirable and in the present classification the term *reverse* is confined to those faults which dip more than 45°. This limiting angle then separates *reverse* from *thrust* as the 90° angle separates *reverse* from *normal* faults.

The term *lateral* is not in common usage but it is obvious, from the number of words used to designate faults with actual or apparent *strike-slip* displacement, that one should be chosen. Clark[12] has chosen *lateral* for good and well expressed reasons, although he applies it to actual displacement and with a genetic significance whereas it is used here to designate *strike-separation* (B of diagram). This aspect of faulting is seen directly in plan (surface or subsurface map) and is equivalent in importance to *dip-separation* (A of diagram) although the tendency is to show or visualize the *dip-separation* so that the terms *normal* or *reverse* can be used. The terms *right* or *left lateral* seem to describe adequately a difference which is considered analogous to, and as important as, the difference between *normal* and *reverse*. Some English workers[13] use the terms *dextral* and *sinistral transcurrent* but with a *slip* instead of *separation* connotation.

Thrust as used here needs justification since it includes any fault which dips less than 45°, shows *dip-separation* and horizontal shortening. Following Suess,[14] any fault which dips less than 45° has a greater component of displacement which

[11] C. M. Nevin, *Principles of Structural Geology*, p. 82. John Wiley and Sons (1931).

[12] Clark, *op. cit.*, p. 1261.

[13] E. M. Anderson, *The Dynamics of Faulting*, p. 55. Oliver and Boyd, London (1942).

[14] E. Suess, *Das Antlitz der Erde*, English Translation, Vol. 1 (1904), p. 106.

is tangential to the earth's surface than radial, thus this angle significantly separates *thrusts* from *reverse* faults. The restriction of the term *thrust* to those faults which show mainly *dip-separation* is, as in the case of *reverse* and *normal*, to separate them from *lateral* faults. Horizontal shortening is a final restriction in the classification to separate *thrusts* from low-dipping *normal* faults.

On some *thrusts* the *dip-separation* is locally down the fault plane due to reversal of original dip or to subsequent folding, but the common component of horizontal shortening still permits the fault to be classified as a *thrust*. Also, occasionally younger or normally higher rocks show a *dip-separation* up and over older or normally lower rocks, but here again horizontal shortening is predominant and the use of the term *thrust* is justified.

The six combination types of faults (aforenamed) are very important because of common occurrence and the three-dimensional connotation of the terms (see diagram of *left lateral normal* fault). In every case where both *dip* and *strike-separation* are evidenced in appreciable amounts, the appropriate combination type name should be used because it is a better characterization of the fault.

This classification is considered practical for apparent rotational[15] displacements by simply describing the variations of apparent displacement along the fault plane by name and/or the character of separation and/or amount of separation. Thus, for example a so-called scissors or pivotal fault could be a *reverse left lateral* in one segment and a *normal right lateral* in the other. It has been suggested[16] that a type locality be designated for each described fault and although this has not been customarily done it would, besides other advantages, be desirable for faults with real or apparent variations of displacement so that these variations could be referred to a specific location on the fault.

The apparent advantages of the fault classification herein proposed are summarized as follows.

1. The classification is practical because it is based principally on apparent displacement (*separation*) which is an ordinarily observed, or at least objectively inferred, aspect of faults.

2. The classification is principally geometric and gives, when both *dip* and *strike-separations* are evidenced, a three-dimensional concept of the apparent displacement (by a combination of terms as the *left lateral normal* fault of the diagram).

3. The classification is simple, but at the same time appears to be refined enough to separate faults into all the groups that are objectively practical and perhaps tectonically significant.

4. The classification comprises generally familiar terms and allows the elimination of a number of other classifications with their abundant terminology.

[15] Reid, *op. cit.*, p. 167.

[16] H. Buddenhagen *et al.*, "Type Locality of Faults," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14 (1930), pp. 797–98.

5. The classification could be used for both previously and newly mapped and described faults.

6. The classification could, because of its avoidance of any implication regarding true relative displacement, focus attention on criteria which are diagnostic of the orientation of *net-slip* and thus stimulate the acquisition of data on faults.

The possible disadvantages of the proposed fault classification are, in part at least, as follows.

1. The classification employs terms which are for the most part ordinarily used, but in a different sense than is customary.

2. The classification is less significant than ones based on origin (e.g., compression, tension and gravity) or relative displacement (e.g., *dip-*, *strike-*, and *oblique-slip*).

3. The classification, if employed too precisely, could result in more terms for a single mapped fault than desirable.

A dual classification of faults might be desirable in cases where, at least the approximate orientation of *net-slip* is known. For example, topographic offset might show recent *strike-slip* movement which could be indicated in the name of the fault, as *right lateral* (*strike-slip*) *normal*. However, such a system of classification is probably not justified until data on *net-slip* are more frequently acquired. Or the classification could be considered as based on *net-slip* with the prefix *apparent* used for the common cases, but experience has shown that the word and its significance can not be retained. Or new terms might be desirable instead of the ones used here in order to eliminate confusion with a *slip*-based terminology, but if it is expressly stated that the *separation*-based classification is used there appears to be no need for the introduction of new terms.

The writer is appreciative of help from discussions on fault classifications with many fellow workers over a period of several years, and of help on the manuscript from Professors James Gilluly, Chester R. Longwell and A. O. Woodford.

TRIASSIC DEPOSITS OF PECOS VALLEY, SOUTHEASTERN NEW MEXICO[1]

WALTER B. LANG[2]
Washington, D. C.

Scattered and isolated exposures of redbeds are displayed in a confusing disarray on the east side of the Pecos River Valley in southeastern New Mexico. These redbeds are older than the deposits of the Gatuña formation (Pleistocene?) but younger than the Permian rocks on which they rest.

[1] Published by permission of the director of the United States Geological Survey. Manuscript received, April 3, 1947.

[2] United States Geological Survey.

The redbeds are of two kinds (1) coarse- to fine-grained arkosic grits, sandstones and siltstones, exhibiting in a striking manner the sedimentary evidence for their terrestrial origin. These beds are referred to as the Santa Rosa sandstone of the Dockum group and are considered to be Upper (?) Triassic in age. The Santa Rosa sandstone seems to be underlain by (2) another sequence of fine-grained, evenly bedded sandstones and siltstones described as the Pierce Canyon redbeds of the Dockum group and also considered to be Upper (?) Triassic in age, though no critical fossil evidence has ever been found in them. Field investigations, however, have disclosed that the Santa Rosa sandstone grades into the Pierce Canyon redbeds and that they are, in part, contemporaneous in origin. The Pierce Canyon redbeds were deposited in a basin of relatively quiet water which occupied a large area of trans-Pecos Texas and a marginal part of southeastern New Mexico. Most of the Pierce Canyon redbeds have been removed by erosion.

PRELIMINARY REPORT ON SALT CREEK FIELD, KERN COUNTY, CALIFORNIA[1]

J. C. BEACH[2]
Bakersfield, California

LOCATION

1. Geographical: McKittrick-Cymric district, on west side of San Joaquin Valley
2. Topographical: Rather flat, surrounded by hills on west, south, and north
3. Derivation of Name: Salt Creek runs through field

DISCOVERY WELL

1. Operator: Independent Exploration Company. Lease and No: Temblor 2
2. Location: 1120′ S., 200′ E. from W. ¼ corner, Sec. 7, T. 29 S., R. 21 E., M.D.B. & M.
3. Completion Date: March 13, 1946. 4. Total depth: 2828′
5. I.P. 480 B/D 18° gravity, 0.1% cut, 17/64 bean, 285 T.P., 430 C.P., 58 Mcf/d, F (F, P, G.L.)
6. Producing Interval: 2790–2828′. Name: Carneros. Age: Miocene

METHOD OF DISCOVERY

Subsurface and surface geology

GEOLOGY

1. Type of Structure: Faulted anticlinal nose
2. Type of Trap: Structural

[1] This is the first in a series of papers sponsored by the Committee for Preliminary Reports on Discoveries of the A.A.P.G. Pacific Section. The committee is composed of George H. Roth, William H. Thomas, and Harold H. Sullwold, Jr., chairman.

[2] Independent Exploration Company.

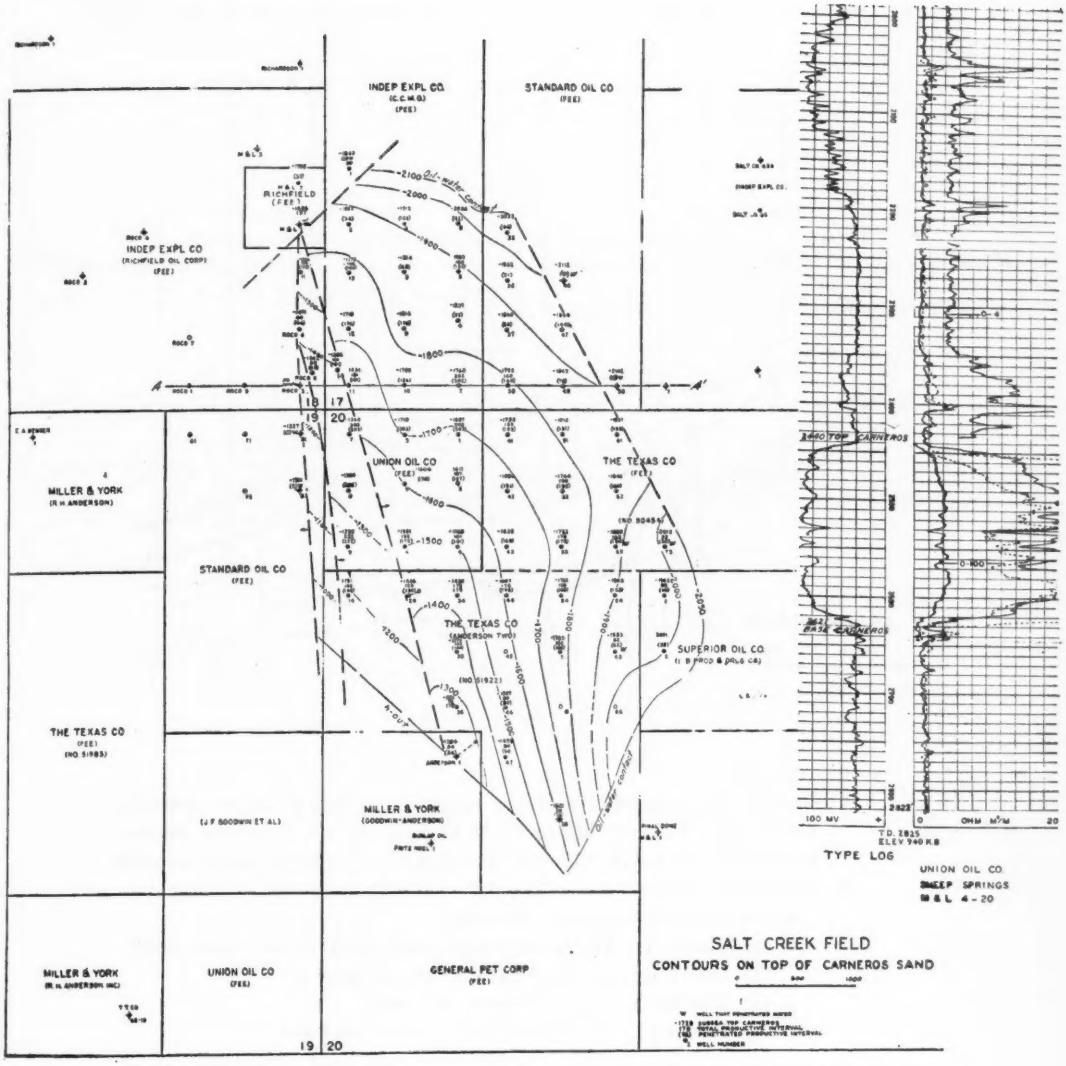

INDEP EXPL CO
(C.C.M.B.)
(FEE)
STANDARD OIL CO
(FEE)
RICHFIELD
(FEE)
INDEP EXPL CO
(RICHFIELD OIL CORP)
(FEE)
-2100 Oil-water contact
-2000
-1900
-1800
-1700
-1600
-1500
-1400
-1300
-1200
-1100
UNION OIL CO
(FEE)
THE TEXAS CO
(FEE)
MILLER & YORK
(R H ANDERSON)
STANDARD OIL CO
(FEE)
THE TEXAS CO
(ANDERSON TWO)
SUPERIOR OIL CO
THE TEXAS CO
(FEE)
MILLER & YORK
(GOODWIN-ANDERSON)
MILLER & YORK
UNION OIL CO
(FEE)
GENERAL PET CORP
(FEE)
18
17
19
20
1840 TOP CARNEROS
BASE CARNEROS
100 MV
OHM M²/M
TD 2825
ELEV 940 K.B
TYPE LOG
UNION OIL CO.
SHEEP SPRINGS
M & L 4 - 20
SALT CREEK FIELD
CONTOURS ON TOP OF CARNEROS SAND

FIG. 1

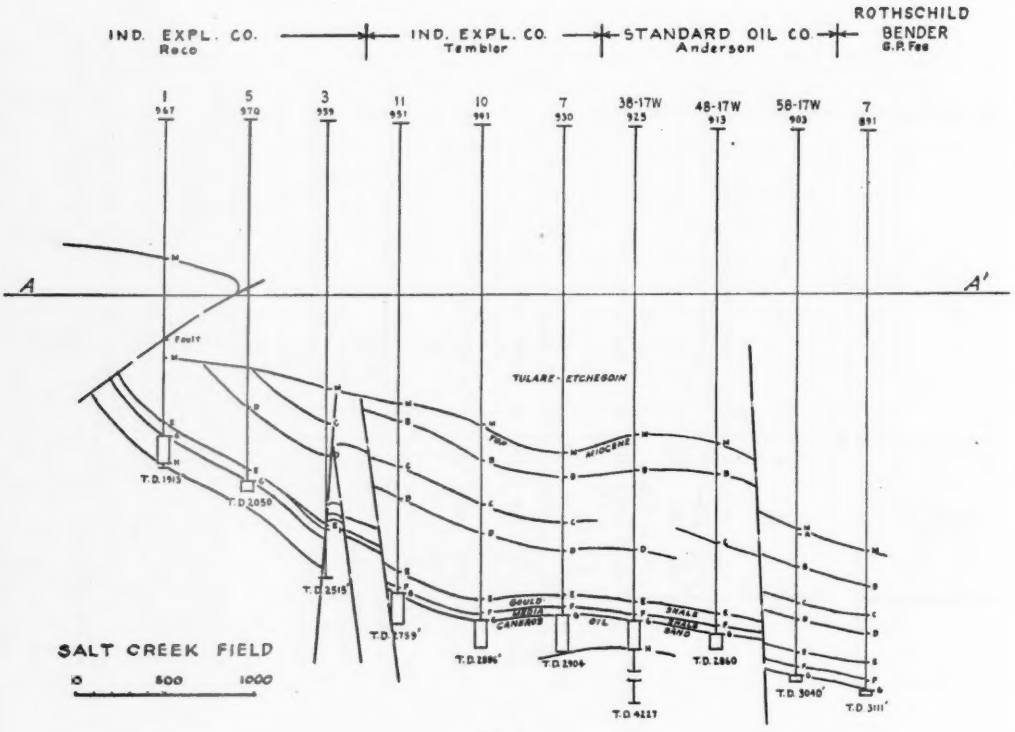


FIG. 2

3. Stratigraphy:
   A. General characteristics and age range of geological section present: Pleistocene (Tulare); Miocene (McDonald, Gould, Carneros, Santos, Phacoides, Salt Creek); Eocene (Point of Rocks). Many unconformities
   B. Producing zone:
      Name and age: Carneros—Miocene
      (1) Character: Medium-grained, well sorted, clean, friable sand
      (2) Depth Range: 1631–2958′ to top of sand
      (3) Thickness: 220 maximum, 95% sand
      (4) Porosity: 33%. Permeability: 1000–3000 Md.
      (5) Average Initial Production: 250 B/D curtailed, 15–22° gravity
      (6) Method of Producing: Flowing
      (7) Water Character: 600–1000 G. C. G.
      (8) Remarks: Well capacities range from 400 to 3000 B/D

4. Deepest Well: Depth: 4227′. Formation at bottom: Point of Rocks sand (Eocene)

PRESENT STATUS (as of May 22, 1947):

1. Number of Producing Wells: 55
2. Number of Dry Holes: 15. 3. Productive acres to date: 300
4. Total B/D of Field: 6500

OUTLOOK

1. Limits of Field Defined? No
2. Section yet Unexplored, deep prospects, *etc.:* Explored to Point of Rocks (Eocene)
3. Proved Reserves: 18,000,000 bbls.

PALEOGEOGRAPHY OF SOUTH AMERICA (CORRECTION)

A regrettable error was made in spelling the title of the article of L. G. Weeks, "Paleogeography of South America," in the listing of the Contents on the cover of the July *Bulletin*. The first word of the title should be PALEOGEOGRAPHY, as it is correctly spelled in the article itself on page 1194.

Editors, reviewers, compilers, those who quote, and those who prepare indexes are respectfully cautioned against this unfortunate lapse.—With apology, J. P. D. HULL.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 31, NO. 9 (SEPTEMBER, 1947), PP. 1678-1687

REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and are available, for loan, to members and associates.

1945 REFERENCE REPORT ON CERTAIN OIL AND GAS FIELDS OF NORTH LOUISIANA, SOUTH ARKANSAS, MISSISSIPPI, AND ALABAMA, VOL. II

REVIEW BY B. COLEMAN RENICK[1]
San Antonio, Texas

1945 Reference Report on Certain Oil and Gas Fields of North Louisiana, South Arkansas, Mississippi, and Alabama, Vol. II (1947). 186 pp., 3 pp. correlation charts, 3 pp. graphical plates, 2 regional maps, 11 plates of electric-log regional cross sections, 5 plates of diagrammatic cross sections, bibliography. Perforated loose-leaf pages, heavy manila cover, plastic ring binder. 8.5×11 inches. Published by Shreveport Geological Society, Box 750, Shreveport, Louisiana. Price, $10.

This is the second volume on oil fields in Louisiana, Arkansas, Mississippi, and Alabama, prepared by the Shreveport Geological Society. Volume I was reviewed by E. Floyd Miller in the March, 1947, *Bulletin*, pp. 529-30. The committee in charge of the preparation of this report consisted of T. H. Philpott, B. W. Blanpied, H. M. Buchner, R. T. Hazzard, F. T. Holden, G. M. Jenkins, L. K. Lancaster, L. H. Meltzer, E. P. Ogier, Van D. Robinson, E. W. Scott, W. C. Spooner, D. F. Tobin, W. E. Wallace, Jr., J. R. Williams, and R. M. Wilson, but there are contributions by a number of geologists in the Louisiana-Mississippi area.

The oil-field descriptions follow the same general pattern as in Volume I, each field description containing a subsurface map, type electric log of the field showing the producing formation or an electric-log cross section. Each description contains Location, Pre-Discovery history, Data on the discovery wells of each producing formation, Structure, Producing zones, Well spacing, Production data, Allowables, Pipe-Line outlets, and miscellaneous information. An 11×21-inch index map shows the oil and gas fields in green and the piercement salt domes in red. All fields and salt domes are numbered by counties and an accompanying index provides ready identification of the name of the field or dome from the number on the map. The location of the electric-log cross sections are also shown on the map.

Volume II contains descriptions of the following fields in Arkansas: Dorcheat-Macedonia, Columbia County; Gum Creek, Ouachita County; Midway, LaFayette County; New London, Union County; Stephens and Smart area, Columbia County, Ouachita and Nevada counties; Urbana, Union County; Village, Columbia County; and Wesson, Ouachita County. The section on North Louisiana contains descriptions of the following fields: Ashland, Natchitoches and Bienville parishes; Athens, Claiborne Parish; Beekman, Morehouse Parish; Benton, Bossier Parish; Big Creek, Richland Parish; Big Island, Rapides Parish; Choudrant, Lincoln Parish; Cotton Valley, Webster Parish; Delhi and West Delhi, Richland and Franklin parishes; Driscoll, Bienville Parish; East Haynesville, Claiborne Parish; Elm Ridge, LaSalle Parish; Larto Lake, Catahoula Parish; Lake St. John, Tensas and Concordia parishes; Manifest, Catahoula Parish; Sailes, Bienville Parish; and Standard in LaSalle and Caldwell parishes.

[1] Consulting geologist, Milam Building. Review received, June 12, 1947.

A very worthwhile addition to this volume is a bibliography of the publications pertaining to the oil and gas fields in South Arkansas, North Louisiana, Mississippi, and Alabama, containing approximately 85 titles. The report also contains a chapter on "Notes on Correlation of the Cretaceous of East Texas, South Arkansas, North Louisiana, Mississippi, and Alabama," by Roy T. Hazzard, B. W. Blanpied, and W. C. Spooner. Besides the description and discussion, this chapter includes two correlation charts which show the correlation of Upper and Lower Cretaceous formations in East Texas, Louisiana, Mississippi, and western Alabama. One chart shows both the surface and subsurface correlations.

Several times during the past 2 years the writer has had the privilege of hearing Hazzard and Blanpied present their interpretation of the correlation of the Woodbine section of Texas with that of Louisiana and Mississippi, and their views are presented in this paper. The Woodbine group is divided by them into three formations with an unconformity at the base which separates it from the Lower Cretaceous. The Woodbine group consists of the following formations from oldest to youngest: the Euless formation containing the basal Dexter sand member below and marine shales above, the Lewisville formation containing the basal Pine Bluff member consisting mostly of reworked volcanic material, and the Eagle Ford formation consisting of sands and dark shales of the East Texas basin and a basal gravelly sand. Each of these formations is separated by an unconformity. The basal Dexter sand member is correlated with the "Massive sand" and the marine shales in the upper part of the Euless are correlated with the "Marine shale" of the lower Tuscaloosa of Mississippi. The Lewisville formation is correlated with the upper Tuscaloosa, and the basal Pine Bluff volcanic member is equivalent to the basal "Chicken Feed" gravel. The name Eagle Ford is introduced in the Mississippi section, and includes beds heretofore called Eutaw in Mississippi.

The name South Tyler formation is introduced to include the beds between theDexter sand and the top of the Buda limestone of the East Texas basin. The Maness copper-colored shales are at the base of this formation. The South Tyler formation is correlated with the Dantzler formation which occurs at a depth of 8,905–9,910 feet in the Humble Oil and Refining Company's B-I Dantzler well, Jackson County, Mississippi.

There is a chapter in this volume on "Notes on the Stratigraphy of the Formations Which Underlie the Smackover Limestone in South Arkansas, Northeast Texas, and North Louisiana" by Roy T. Hazzard, W. C. Spooner, and B. W. Blanpied. The interpretations of the authors of this chapter completely revise previous concepts of the pre-Smackover stratigraphy as described by Imlay[2] and Imlay and Williams.[3] The most important changes in the authors' interpretation of the pre-Smackover stratigraphy are briefly referred to in this review, but anyone interested in this section of rocks within the area between Mexico and Alabama should by all means read this chapter. Imlay[4] in describing the Eagle Mills formation subdivided it into the Louann tongue, the Eagle Mills salt and the Norphlet tongue, named in ascending order, and interpreted it as Jurassic in age. The Morehouse formation was considered to be of "late Paleozoic age not older than Pennsylvanian" and to underlie the Eagle Mills formation. Above the Eagle Mills formation of Imlay is the Smackover limestone of Jurassic age.

[2] R. W. Imlay, "Lower Cretaceous and Jurassic Formations of South Arkansas, and Their Oil and Gas Possibilities," *Arkansas Geol. Survey Inform. Cir. 12* (1940).

———, "Jurassic Formations of Gulf Region," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27, No. 11 (November, 1943), pp. 1407–1533.

[3] R. W. Imlay and J. S. Williams, "Late Paleozoic Age of Morehouse Formation of Northeast Louisiana," *ibid.*, Vol. 26, No. 10 (October, 1942), pp. 1672–73.

[4] R. W. Imlay, "Jurassic Formations of Gulf Region," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27, No. 11 (November, 1943), pp. 1407–1533.

The correlation table of the pre-Smackover rocks is reproduced here. Attention is called to Imlay's correlation which included the Louann tongue, the Salt or Redbed clastics, and the Norphlet tongue in the Eagle Mills formation which he assigned to the Jurassic, and underlying this sequence, the Morehouse formation of late Paleozoic age. The authors of this volume however, include only the Norphlet formation (Redbeds with or without gravel) in the Jurassic (Upper) and believe that an unconformity separates this formation from the underlying Louann salt which together with the underlying Werner formation (Anhydrite member and redbeds and gravel) they assign to the Permian. Below the

TABLE I

	Former Interpretation of Stratigraphic Sequence		*Authors' Interpretation of Stratigraphic Sequence*	
	Unconformity			
	Buckner formation		Buckner formation	Jurassic
	Smackover limestone		Smackover limestone	
Jurassic	Eagle Mills formation	Norphlet tongue	Norphlet formation Redbeds with or without gravel	
			Unconformity	
		Salt or Redbed clastics	Louann salt	Permian
		Louann tongue	Werner formation Anhydrite member and Redbed and Gravel member	
			Unconformity	
Late Paleozoic	Morehouse formation		Morehouse formation	
			Eagle Mills formation	

Werner formation and separated by another unconformity is the Morehouse formation which is above their Eagle Mills formation, both of which are regarded as Permian.

This chapter on the pre-Smackover rocks also contains a very comprehensive discussion concerning the mode and environment during the deposition of the Werner anhydrite and Louann salt-evaporite sequence. Experimental data by Usiglio on evaporation of the Mediterranean Sea waters are discussed in considerable detail. Anyone concerned with the deposition of anhydrite, salt, and associated evaporites is referred to this chapter. It should be of especial interest to West Texas geologists. The authors believe that the thickness of the Louann salt is an approximate measure of the original depth of the Texas, Arkansas, Louisiana part of the Louann basin, and that inflow of concentrated brines into this basin with saline concentrations near the sodium chloride precipitation point eventually filled this basin with salt precipitates. Arguments are presented in this section for including the Werner-Louann sequence in the Permian system; the authors consider that these evaporites represent an unbroken cycle of precipitation. The unconformity between the Louann salt (Permian) and the Norphlet formation (basal Upper Jurassic of tri-state area) probably represents Triassic, Lower Jurassic, and Middle Jurassic time. The Louann salt is estimated to underlie an area of approximately 180,000 square miles and is assumed to have had an original maximum area of 200,000–250,000 square miles. This is compared with the Castile salt basin which is estimated to be approximately 10,000 square miles in extent.[5]

[5] P. B. King, "Permian of West Texas and Southeastern New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26, No. 4 (April, 1942), pp. 535–763.

Accompanying this chapter is a map showing the northern limits of the several pre-Cretaceous formations described in the report and accompanying cross sections showing the stratigraphic relations.

A statistical table covering the fields of southern Arkansas, Louisiana, Mississippi, and Alabama, gives the name of the field, county, year discovered, producing formation, age of producing formation, depth of producing formation, gravity, productive acres, accumulative production in barrels of oil, and condensate, and MCF of gas. Included in the report are eleven regional electric-log sections and three diagrammatic cross sections. These sections show the stratigraphic relations and changes between East Texas, southern Arkansas, northern Louisiana, Mississippi, and Alabama. The numerous gradations and unconformities in the Cretaceous and underlying formations are clearly depicted. It is impractical to describe these sections in detail in a review but suffice it to say that they should form the basis for any geologist who desires to study the subsurface stratigraphy of any of the areas mentioned. The electric-log sections are reproduced in this volume on a scale of 1 inch equals 500 feet, and accompanying the report is a notice that these sections may be purchased separately on a scale of 1 inch equals 500 feet at an approximate cost of printing plus 25 per cent. Sections are also available from the original drawings on a scale of 1 inch equals 100 feet, and may be ordered as individual sections at a cost of printing plus 25 per cent. It is estimated that the cost of all sections published in Volumes I and II on the scale of 1 inch equals 100 feet would cost approximately $40; they are available from the Shreveport Geological Society, Box 750, Shreveport, Louisiana.

The authors of this report are to be congratulated on furnishing the geological profession with this volume as well as Volume I. The stratigraphy and structure as reflected in these volumes represent the mature opinion of many geologists of the region—Hazzard, Blanpied, Spooner, Moody, to mention a few—as well as numerous other geologists in the area, many of whom have studied this area intensively for 20 years or longer. Volumes I and II should be available in the library of any geologist who is interested in the Cretaceous and pre-Cretaceous geology between the Atlantic seaboard and Mexico.

ROCKHOUNDS OF HOUSTON, BY ALVA C. ELLISOR

REVIEW BY A. R. DENISON[1]
Tulsa, Oklahoma

Rockhounds of Houston, by Alva C. Ellisor. 99 pages. Published by the Houston Geological Society (1947). No figures or illustrations.

The sub-title of this publication—"An informal history of the Houston Geological Society"—is very modest and distinctly an understatement. This brief but compact publication after "looking backward" to recount the beginnings of oil elsewhere in the world, takes up the history of the oil industry in Texas and skillfully weaves into it the part which geologists played in its progress.

The prologue recites that "These Houston Rockhounds have participated in the most colorful era of the petroleum industry—his geologic problems have been most challenging —some of the most famous names in (the) geologic profession have been or are members of the Houston Society."

The territory covered by the society is the area in which several of the new or revolutionary techniques were introduced which have been adopted throughout the oil industry such as: micropaleontology in 1920, geophysics in 1922–1924, and electric logging in 1932.

[1] Review received, June 5, 1947.

The problems faced by the Houston geologists have indeed been challenging first in connection with the shallow salt domes and in the latter era with the deeper structures ushered in by the discovery of Conroe. Without doubt the society has had or has as members a long list of distinguished geologists—among those presently members being the two Sidney Powers Memorial Medalists—Wallace Pratt and Alexander Deussen. Its claim, however, to having "ten past presidents, one-third of the total" stands on less firm ground since only five of these were living in Houston at the time of their elevation to office.

Rockhounds in Houston met informally as early as 1920, but formal organization was not effected until August, 1923. There were 73 charter members—14 of whom still reside in Houston. The growth was slow and at the end of eight years the membership had not reached 150. By this time it was a well knit group who were experts and specialists on salt-dome geology. The discovery of the Conroe field in 1931 did more to stimulate the society than any single event. It brought a new trend of exploration and, in the words of the author, "Many geologists flocked into Houston" bringing "new ideas [which] jarred the Houston geologists out of their comfortable rut." The membership reflected this influx which, following a sharp increase, has steadily increased to 456 paid-up members (June, 1946). As of that date it could boast of being the largest organized local group of geologists in the world.

In addition to excellent biographical sketches of pioneer geologists, outstanding members and others, there is space devoted to the three A.A.P.G. conventions held under the society's sponsorship, a discussion of field trips, study groups and other activities of the society. It also contains a list of all officers, past and present members, and the programs of the society for the years 1929 to 1946, inclusive. A brief list of references concludes the publication.

The Houston society is to be congratulated on the initiation of this fine historical item and is particularly fortunate to have as the editor, Miss Ellisor, who has herself participated in the entire life of the society and was its first elected vice-president, an office which she also held in 1930-1931.

This publication will be eagerly sought by all past and present members of the society and is a "must" for every geologist who has any interest in application of geology to the search for oil—which should easily cover the entire membership of the Association.

EINFÜHRUNG IN DEN BAU AMERIKAS, BY HANS STILLE

REVIEW BY W. A. VER WIEBE[1]
Wichita, Kansas

Einführung in den Bau Amerikas (Introduction to the Construction of the American Continents), by Hans Stille. 717 pp., 128 figs. Gebrüder Borntraeger, Berlin, Germany (1940). Text in German.

Probably the most comprehensive geological treatise to come out of Germany since the end of the war is this monograph on the structural history of the western hemisphere. Although it involves over 700 pages, it must nevertheless be called a concise presentation of all previously recorded facts regarding the architecture of North America, Central America, and South America. The author relies on the literature, but does not hesitate to express his own opinion on controversial matters. Considering the fact that he has a profound background of geological information from other parts of the world, his opinion must be respected.

[1] Professor of geology at the University of Wichita.

Review received, June 14, 1947.

The introductory chapter presents the tectonic principles which form the basis for the following chapters. Three orogenic "eras" are described which span the time since the end of the Cambrian period. The oldest era is the Caledonian which has four phases marking points of time from the beginning of the Ordovician to the end of Silurian time. The Variscan era has six phases—begins at the close of Devonian time and ends with the close of Paleozoic time. The youngest orogenic era—the Alpine—begins with the orogenic disturbance closing Triassic time and includes the numerous phases up to and including the Pleistocene. In addition to a complete presentation of orogenic events in the western hemisphere the author also devotes considerable space to related facts of stratigraphy and geosynclinal history. In discussing geosynclines Dr. Stille likes to define an orthogeosyncline as one which has great longitudinal extent as compared with a rather narrow width and which is furthermore characterized by "green" rocks in the accompanying magmatic intrusions. He includes in the concept what Schuchert called polygeosynclines. In following this concept to its logical limit he is inclined to consider "borderlands" as portions of an orthogeosyncline. Thus the idea of a borderland of Appalachia, for example, is questioned and the Piedmont Plateau region is regarded not as a part of the continent, but merely as a part of the original geosyncline which was uplifted and consolidated rather early in the geosyncline history. Following this thought somewhat further, the principle of Dana "once a continent always a continent" loses its meaning and a new concept replaces it. This is the thesis that a continent contains an original nucleus (kraton) against which the newer portions of the continent are swedged by repeated orogenies. In other words we must think of three categories of space relation: (a) large continental blocks (high kratons); (b) zones which are mobile and deformable, that is, the orthogeosynclines; and (c) deep-seated blocks on the non-deformable oceanic areas.

In sketching the structural history of the various parts of the western hemisphere the author has apparently neglected no item of published information. In his search for fundamental facts and a penetrating analysis of these facts, the author draws comprehensive pictures of large regions and then proceeds to give local details to complete the picture for the reader. This involves somewhat lengthy and often rather minute stratigraphic discussions. For parts of the north American continent our members will find themselves on familiar ground. Furthermore, the author can discuss these areas with considerable confidence since the available information is abundant. For other parts, such as Canada, Alaska, and Mexico, there is considerable information which most of our members will welcome because the original source material is relatively unfamiliar.

South America is described with remarkable completeness, considering the paucity of available data. In the search for new oil fields on that continent a real understanding of the tectonics of the various countries will prove extremely valuable and here is where our members may find their greatest reward. The tectonics of Colombia and Venezuela have been presented in some recent papers in the *Bulletin* and for those countries Dr. Stille's book adds little. However, for the other countries of South America the opposite is undoubtedly true. The Antillean region is perhaps the most complicated patchwork of tectonic blocks in the world. To make even a reasonably accurate picture of its structural history requires not only knowledge but a prodigious imagination. The reviewer believes that Dr. Stille's discussion of this area will later be found the most appreciated part of his book.

In addition to the text matter there is a good glossary of terms (9 pages), a very complete bibliography (15 pages of small type), an author index, and a place index. All the material is in German.

LATE MESOZOIC AND EARLY CENOZOIC HISTORY OF CENTRAL UTAH, BY EDMUND M. SPIEKER

REVIEW BY C. E. DOBBIN[1]
Denver, Colorado

"Late Mesozoic and Early Cenozoic History of Central Utah," by Edmund M. Spieker. *U. S. Geol. Survey Prof. Paper 205-D* (1946), pp. 117–61.

This concise and scholarly paper covers a classic district that has fulfilled the hopes of G. K. Gilbert and others that it might furnish the key to solving much regional geology. Featured by the choicest of diction, the excision of the superfluous, and the summary application of fundamental principles to the Cretaceous-Tertiary problem, the paper shows how the discovery of dinosaur bones in strata of central Utah, formerly assigned to the Eocene Wasatch formation, and other findings, have made it possible to outline late Mesozoic and early Cenozoic history considerably different from the scheme hitherto conceived; it shows that in certain elements of stratigraphic and orogenic succession the record of physical events for the late Mesozoic is possibly more complete in central Utah than elsewhere in North America; and it demonstrates in the time span covered by the paper three orogenies: (1) an early Upper Cretaceous movement in the eastern part of the Great Basin, (2) an early Laramide movement—the main Laramide orogeny of central Utah—between middle and late Montana time, instead of at the end of the Cretaceous, as formerly thought, and (3) a pre-Flagstaff movement, which probably occurred in Paleocene time.

After describing in detail two equivalent but notably different sections of Upper Jurassic to Eocene strata in central Utah and showing how the deciphering of their relations influenced the main conclusions presented, the author discusses the Larmide and other major geological problems as affected by his findings in central Utah. He shows that since 1869, when Hayden proposed the name Wasatch, the usage of the name has been far from uniform, that the type section probably covers a stratigraphic range too extensive for practical purposes, that the Wasatch of the areal geologist has only slightly coincided with that of the vertebrate paleontologist, that the name has become essentially a generalized term covering the whole lower Eocene, and that until the actual content of the type section is carefully worked out, regional use of the term in a strictly typical sense will be impossible.

The Cretaceous-Tertiary boundary problem (the Laramide problem), is discussed in the light of general principles—"an examination of certain governing principles and concepts that seem to be crucial." The author raises the question whether there is a valid general basis for the subdivision of geologic time, and secondarily, if there is a basis usable to characterize the larger subdivisions, can it be applied to the exact determination of boundaries? He shows how the time pattern of the earth's orogenic performance does not match the pattern of subdivision based on fossil succession, how in central Utah the major Laramide folding took place a long time before any of the important changes in the fossil record that have been argued as division markers. He reasons for multiplicity of orogenic activity, and concludes that the postulate of world-wide simultaneity in late Mesozoic and early Tertiary orogenies is not well enough demonstrated to be relied on either in correlation or the establishment of divisions in the time scale, and that subdivision on purely epeirogenetic grounds is difficult. Stating that in the present problem it is logical to put the boundary at the horizon at which the greatest change takes place in total fossil assemblage from characteristically Cretaceous to characteristically Tertiary, the author draws

[1] Regional geologist, United States Geological Survey.

Review received, June 25, 1947.

the boundary between the Lance and the Fort Union formations in the Great Plains Province and points west and in the North Horn formation of central Utah, for below the boundary as thus drawn is a dinosaurian fauna and above are mammalian faunas of Paleocene age, the boundary in the North Horn formation being unrecognizable by known physical criteria. He states that the changes that occur between the Danian and the Montian of Europe are similar, and that the European geologists have been drawing the boundary at this horizon for some time; in fact, the floras of the Lance and Fort Union are evidently distinct, even though the great changes in the plant world have occurred, in general, at times different from those in the animal world.

As originally applied, the term "Laramide" was meant to designate a single great disturbance separating the Cretaceous from the Tertiary. According to the author, the structures attributed to this disturbance are now seen to have resulted from a succession of movements beginning not later than the early Upper Cretaceous and continuing through the Tertiary to the verge of the Quaternary; perhaps even later. He suggests, therefore, that it would be more appropriate to restrict the term "Laramide" to the group of movements that occurred in the later part of the Upper Cretaceous and the early part of the Tertiary, certainly not going beyond Eocene time.

LEVEN EN MATERIE, BY J. H. F. UMBGROVE

REVIEW BY PARKER D. TRASK[1]
Washington, D. C.

Leven en Materie (Life and Matter), by J. H. F. Umbgrove. Martinus Nijhoff, 's Gravenhage, Holland. 3d edit. (1946). 150 pp., 65 figs. In Dutch. Price, Gld. 8, 60.

Dr. Umbgrove has written an interesting summary of evolution and evolutionary processes. His book is replete with illustrations, taken largely from other authors. He approaches evolution from the point of view of a geologist, describing in some detail the four classic concepts: environment (adaptive radiation), mutation, orthogenesis, and natural selection. To these factors he would add two others: (1) life and its metabolic processes, and (2) inanimate physico-chemical processes. These last two he describes as *life* and *matter*. He regards the four classic concepts mentioned above as being really manifestations of the inter-reactions of life and matter upon each other.

In his last chapter he attempts to show that, basically, biologic or metabolic processes are remarkably similar to physico-chemical processes. The principal difference as he sees it is the power of self-direction in living things; yet as he points out, certain definitely inanimate objects, such as crystals, grow according to well circumscribed conditions, which though not exactly analogous to the self-direction of life, in some ways are not so different. He suggests that incipient mutations in germ plasm may be analogous to pulsations of matter, postulated by Bohr in his quantum theory. He also feels that entropy has an important effect on evolutionary processes.

One interesting feature, in his concept of life and matter, is a chart based on work of Bass-Becking, which shows that the relative concentrations of chemical elements in living matter, on the whole, are greater than in sea water and less than in the lithosphere. The most fascinating feature in the book to the reviewer, however, is a diagram, taken from Kluyver, which portrays an evolutionary trend from non-living toward living objects with

[1] United States Geological Survey.

Review received, June 11, 1947.

increase in size of certain molecules or combinations of molecules. Umbgrove points out that relatively small objects, such as molecules of water or simple proteins, are definitely inanimate; other objects, slightly larger in size, such as many of the filterable viruses, have both animate and inanimate properties; and still larger though minute objects, such as bacteria and algae, are definitely living things. He offers no tangible theory as to how life develops from inanimate material, but he reiterates that there must be a natural basis for living protoplasm. He believes that physico-chemical and biochemical studies of material of ultra-microscopic or sub-microscopic size, ultimately will yield useful clues toward the solution of the mysteries of life and evolution.

The book though essentially a compilation, is highly imaginative and provocative. Unfortunately, it is written in the Dutch language. Were it in English, many Americans would read it avidly.

RECENT PUBLICATIONS

BRAZIL

* "Oil Possibilities of Brazil's Parana Basin," by Oscar B. Irizarry. *Petroleo Interamericano*, Vol. 5, No. 8 (Tulsa, August, 1947), pp. 34–39, 60; map, photographs, statistics. In Spanish and English.

COLOMBIA

* *Compilacion de los Estudios Geologicos Oficiales en Colombia*, Tomo VII (Bogota, 1947). 346 pp. Approx. 6.75×9.75 inches. Paper cover. 23 articles by 10 authors. In Spanish and English.

COLORADO

"Structure Contour Map of the Surface Rocks of the Model Anticline, Las Animas County, Colorado," by N. W. Bass. *U. S. Geol. Survey Prelim. Map 68*, Oil and Gas Investig. Ser. (July, 1947). Sheet, 34×46 inches. Scale, 1.5 inches equals 1 mile. For sale by Director, Geological Survey, Washington 25, D. C. Price, $0.25.

* "Oil-Shale Demonstration Plant," from *U. S. Bur. Mines News Release. Petrol. Eng.*, Vol. 18, No. 11 (Dallas, July, 1947), pp. 87–99; 3 photographs, 1 map.

"Map of Colorado Showing Dry Holes and Oil and Gas Fields," compiled by Flora K. Demok, H. R. Castor, and N. W. Bass. *U. S. Geol. Survey Prelim. Map 73*, Oil and Gas Investig. Ser. (July, 1947). Sheet, 44×64 inches. Scale, 1 inch equals 8 miles. For sale by Director, Geological Survey, Washington 25, D. C. Price, $0.40.

FLORIDA

"The Molluscan Fauna of the Alum Bluff Group of Florida, Part VIII, Ctenobranchia (Remainder), Aspidobranchia, and Scaphopoda," by Julia Gardner. *U. S. Geol. Survey Prof. Paper 142-H* (June, 1947), pp. 493–656, Pls. 52–62. For sale by Supt. Documents, Govt. Printing Office, Washington 25, D. C. Price. $1.00.

GENERAL

* "Utilization of Logging Data in Estimating Oil Reserves," by I. Kogan. *Petrol. Eng.*, Vol. 18, No. 11 (Dallas, July, 1947), pp. 54–60; 6 figs. Published in *Azerbaidzhanskoe Neftianoe Khoziaistvo*, No. 10/11 (Baku, 1935), pp. 15–20.

* "Symposium on Pennsylvanian Problems," by Harold R. Wanless *et al. Jour. Geol.*, Vol. 55, No. 3, Pt. II (Chicago, May, 1947), pp. 183–308, illus. 11 articles by 9 authors.

HAITI

"Bulimina and Related Foraminiferal Genera," by J. A. Cushman and F. L. Parker. *U. S. Geol. Survey Prof. Paper 210-D* (June, 1947), pp. 55–176, Pls. 15–30. For sale by Supt. Documents, Govt. Printing Office, Washington 25, D. C. Price, $0.55.

"Publications of the Geological Survey" (not including topographic maps), May, 1947 (1947). 300 pp. Free on application to Director, Geological Survey, Washington 25, D.C.

* "Modern Developments in Geophysical Prospecting," by A. Van Weelden. *Jour. Inst. Petroleum*, Vol. 33, No. 282 (London, 1947), pp. 344–55.

* "Bacterial Release of Oil from Sedimentary Materials," by Claude E. ZoBell. *Oil and Gas Jour.*, Vol. 46, No. 13 (Tulsa, August 2, 1947), pp. 62–65, photographs.

"Upper Cretaceous Ammonites from Haiti," by J. B. Reeside, Jr. *U. S. Geol. Survey Prof. Paper 214-A* (June, 1947), pp. 1–11, Pls. 1–3. For sale by Supt. Documents, Govt. Printing Office, Washington 25, D. C. Price, $0.15.

KANSAS

* "Exploration for Oil and Gas in Western Kansas During 1946," by Walter A. Ver Wiebe. *Kansas Geol. Survey Bull. 68* (Lawrence, July, 1947). 111 pp., 30 figs., 42 tables.

* "Solution Features on Cretaceous Sandstone in Central Kansas," by John C. Frye and Ada Swineford. *Amer. Jour. Sci.*, Vol. 245, No. 6 (New Haven, June, 1947), pp. 366–79; 1 fig., 4 pls., 2 tables.

* "Buried Pre-Cambrian Hills in Central Kansas," by Robert F. Walters. *World Oil*, Vol. 126, No. 10 (Houston, August 4, 1947), pp. 28–33; 4 figs.

OHIO

"Waynesburg Coal in Harrison and Northern Belmont Counties, Ohio, and Revision of Dunkard (Permian) Boundary," by George W. White. *Ohio Geol. Survey Rept. Inv. 1* (Columbus, 1947). 6 pp. Folded colored map and sections. Free.

"Geologic Section of the Chillicothe Test Core," by J. Ernest Carman. *Ibid., Rept. Inv. 2.* 6 pp. Free.

Maps Showing Outcrop and Extent of Meigs Creek Coal in Cumberland and Caldwell Quadrangles. Each map in 3 colors on topographic base. Scale, 1 inch equals 1 mile. Accompanied by sections of coal. Geological Survey of Ohio, Ohio State University, Columbus, Ohio. Price of 2 maps and sheet of sections, $0.25.

VIRGINIA

* "Thrust-Shatter Theory of Oil Accumulation," by Willard Rouse Jillson. *World Oil*, Vol. 126, No. 10 (Houston, August 4, 1947), pp. 40–42; 2 figs.

WEST VIRGINIA

* "Future of Oil in West Virginia," by Paul H. Price, R. C. Tucker, and James H. C. Martens. *Producers Monthly* (Bradford, Pennsylvania, July, 1947), pp. 19–24; 1 map.

* *Ibid., Oil and Gas Jour.*, Vol. 46, No. 15 (Tulsa, August 16, 1947), pp. 104, 107, 109–10; 1 map.

WYOMING

"Areal and Structural Geology of the Mush Creek Area, Weston County, Wyoming," by C. E. Dobbin, George H. Horn, and J. Alliger. *U. S. Geol. Survey* (1947). Scale, 1 inch equals 1 mile. For sale by Director, Geological Survey, Washington 25, D. C. Price, $0.10.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 31, NO. 9 (SEPTEMBER, 1947), PP. 1688-1697

THE ASSOCIATION ROUND TABLE

ASSOCIATION COMMITTEES

EXECUTIVE COMMITTEE

CARROLL E. DOBBIN, *chairman*, United States Geological Survey, Denver, Colorado
J. V. HOWELL, *secretary*, Consultant, Tulsa, Oklahoma
EARL B. NOBLE, Union Oil Company of California, Los Angeles, California
GEORGE S. BUCHANAN, Sohio Petroleum Corporation, Houston, Texas
CLARENCE L. MOODY, The Ohio Oil Company, Shreveport, Louisiana

REPRESENTATIVE ON DIVISION OF GEOLOGY AND GEOGRAPHY NATIONAL RESEARCH COUNCIL: PHILIP B. KING (1949)

REPRESENTATIVES ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

W. TAYLOR THOM, JR. ROBERT J. RIGGS

COMMISSIONERS ON AMERICAN COMMISSION ON STRATIGRAPHIC NOMENCLATURE

M. G. CHENEY (1947), *chairman* JOHN G. BARTRAM (1948) WAYNE V. JONES (1949)

STANDING COMMITTEES

FINANCE COMMITTEE

JOSEPH E. POGUE (1948), *chairman* JOHN S. IVY (1949) E. O. MARKHAM (1950)

TRUSTEES OF REVOLVING PUBLICATION FUND

W. B. WILSON (1948), *chairman* WILLIAM B. HEROY (1949) HAROLD W. HOOTS (1950)

TRUSTEES OF RESEARCH FUND

T. S. HARRISON (1948), *chairman* ROBERT W. CLARK (1949) ROY R. MORSE (1950)

BUSINESS COMMITTEE

THEODORE A. LINK (1948), *chairman*, Imperial Oil, Ltd., Toronto, Ontario, Canada
BEN H. PARKER (1948), *co-chairman*, Colorado School of Mines, Golden, Colorado

C. I. ALEXANDER (1949)
WARREN D. ANDERSON (1948)
FRANK W. BELL (1948)
GORDON R. BELL (1949)
OLIN G. BELL (1948)
ALBERT F. BARRETT (1949)
B. W. BLANPIED (1949)
REUEL L. BOSS (1949)
IRA A. BRINKERHOFF (1948)
GEORGE S. BUCHANAN (1948)
H. E. CHRISTENSEN (1948)
CHARLES K. CLARK (1949)
FRANK R. CLARK (1948)
GEORGE H. COATES (1949)
C. S. CORBETT (1949)
CARLE H. DANE (1948)
CARROLL E. DOBBIN (1949)
STANLEY G. ELDER (1948)
FENTON H. FINN (1949)
W. DOW HAMM (1948)
HOLLIS D. HEDBERG (1949)
FREDERICK G. HOLL (1949)
J. W. HOOVER (1949)
J. V. HOWELL (1948)
W. S. W. KEW (1949)
ROBERT L. KIDD (1948)
G. M. KNEBEL (1948)
ROBERT N. KOLM (1948)
H. G. KUGLER (1948)
CHARLES L. LAKE (1949)
CLAUDE E. LEACH (1948)
LYNN K. LEE (1949)
SHIRLEY L. MASON (1948)
O. G. MCCLAIN (1949)
F. H. MCGUIGAN (1949)
E. FLOYD MILLER (1949)
CLARENCE L. MOODY (1948)
EARL B. NOBLE (1948)
ELISHA A. PASCHAL (1948)
J. M. PATTERSON (1949)
E. E. Rehn (1949)
J. J. RUSSELL, JR. (1948)
JOHN T. SANFORD (1949)
LOWELL W. SAUNDERS (1949)
HARRY C. SPOOR, JR. (1949)
HENRYK B. STENZEL (1948)
D. E. TAYLOR (1948)
HENRY N. TOLER (1949)
C. W. TOMLINSON (1948)
JAMES A. WATERS (1948)
SAM H. WOODS (1949)

COMMITTEE FOR PUBLICATION

LYNN K. LEE (1948), *chairman*, Pure Oil Company, Fort Worth, Texas

1948	1949	1950
JOHN E. GALLEY	JOHN G. GRAY	LAURENCE C. HAY
W. S. HOFFMEISTER	GEORGE C. GROW	HOLLIS D. HEDBERG
J. M. KIRBY	BENJAMIN F. HAKE	G. L. MEHOLIN
E. RUSSELL LLOYD	MASON L. HILL	E. FLOYD MILLER
HOMER A. NOBLE	GEORGE S. HUME	VINCENT C. PERINI, JR.
THOMAS F. STIPP	JAMES A. MOORE	PAUL H. PRICE
C. W. WILSON, JR.	ROBERT B. NEWCOMBE	E. E. REHN
	E. A. WENDLANDT	J. K. ROGERS
		K. K. SPOONER

RESEARCH COMMITTEE

SHEPARD W. LOWMAN (1948), *chairman*, Shell Oil Company, Houston, Texas

1948	1949	1950
RONALD K. DEFORD	L. C. CASE	ROLAND F. BEERS
MARCUS A. HANNA	PARKE A. DICKEY	G. C. GESTER
MARSHALL KAY	K. C. HEALD	JOHN T. LONSDALE
PHILIP B. KING	WILLIAM C. IMBT	C. V. MILLIKAN
A. I. LEVORSEN	W. C. KRUMBEIN	L. L. NETTLETON
W. W. RUBEY	ROBERT J. RIGGS	JOHN T. ROUSE
W. T. THOM, JR.	F. M. VAN TUYL	W. H. TWENHOFEL
L. G. WEEKS	W. A. WALDSCHMIDT	CLAUDE E. ZOBELL

GEOLOGIC NAMES AND CORRELATIONS COMMITTEE

HENRY J. MORGAN, JR. (1948), *chairman*, Atlantic Oil and Refining Company, Dallas, Texas

1948	1949		1950
JOHN G. BARTRAM	A. E. BRAINERD	HORACE G. RICHARDS	STUART K. CLARK
ROBERT H. DOTT	ROLLIN ECKIS	GAYLE SCOTT	ROY T. HAZZARD
E. FLOYD MILLER	ROSS L. HEATON	G. D. THOMAS	W. J. HILSEWECK
HUGH D. MISER	J. H. C. MARTENS	H. D. THOMAS	P. H. JENNINGS
RAYMOND C. MOORE	TOM MCGLOTHLIN	ROBERT O. VERNON	WAYNE V. JONES
	GROVER E. MURRAY	L. E. WORKMAN	W. ARMSTRONG PRICE
			H. A. TOURTELOT

SUB-COMMITTEE ON CENOZOIC

GROVER E. MURRAY (1949), *chairman*, Magnolia Petroleum Company, Jackson, Mississippi

ROBERT O. VERNON (Atlantic Coast)
ROLLIN ECKIS (Pacific Coast)
TOM MCGLOTHLIN (Eastern Gulf Coast)
PHILIP H. JENNINGS (Western Gulf Coast)
HARRY A. TOURTELOT (Rocky Mts. and Great Plains)

SUB-COMMITTEE ON MESOZOIC

G. D. THOMAS (1949), *chairman*, Shell Oil Company, Inc., Shreveport, Louisiana

R. T. HAZZARD (Gulf Coast)
ROSS L. HEATON (Rocky Mts. and Great Plains)
HORACE G. RICHARDS (Atlantic Coast)

SUB-COMMITTEE ON PALEOZOIC

ROBERT H. DOTT (1948), *chairman*, Oklahoma Geological Survey, Norman, Oklahoma

H. D. THOMAS (Rocky Mts. and Great Plains)
STUART K. CLARK (Mid-Continent)
L. E. WORKMAN (Eastern Interior)
W. J. HILSEWECK (Southwestern U. S. A.)
J. H. C. MARTENS (Appalachian Region)

ADVISORY AND SPECIAL PROJECTS SUB-COMMITTEE

JOHN G. BARTRAM (1948), *chairman*, Stanolind Oil and Gas Company, Tulsa, Oklahoma

ARTHUR E. BRAINERD	E. FLOYD MILLER	RAYMOND C. MOORE
WAYNE V. JONES	HUGH D. MISER	W. ARMSTRONG PRICE
		GAYLE SCOTT

COMMITTEE ON APPLICATIONS OF GEOLOGY

KENNETH K. LANDES (1948), *chairman*, University of Michigan, Ann Arbor, Michigan

1948	1949	1950
ROBERT I. DICKEY	E. M. BAYSINGER	DON L. CARROLL
CHARLES R. FETTKE	CHARLES J. DEEGAN	STANLEY G. ELDER
OLAF P. JENKINS	L. B. HERRING	LEO R. FORTIER
NICHOLAS A. ROSE	R. A. STEHR	THOMAS A. HENDRICKS
		W. T. NIGHTINGALE
		W. T. SCHNEIDER

MEDAL AWARD COMMITTEE

CARROLL E. DOBBIN, *chairman*, U. S. Geological Survey, Denver, Colorado
JAMES A. WATERS, *ex officio*, president of S.E.P.M.
CECIL H. GREEN, *ex officio*, president of S.E.G.

1948	1949	1950
A. RODGER DENISON	RUSSELL S. MCFARLAND	FRANK R. CLARK
VIRGIL B. COLE	RAYMOND F. BAKER	ALFRED H. BELL
J. EDMUND EATON	C. R. MCCOLLOM	A. E. BRAINERD

COMMITTEE ON STATISTICS OF EXPLORATORY DRILLING

F. H. LAHEE (1950), *chairman*, Sun Oil Company, Box 2880, Dallas, Texas
PAUL WEAVER (1948), *vice-chairman*, Gulf Oil Corporation, Box 2100, Houston, Texas

1948	1949	1950
KENNETH COTTINGHAM	STANLEY G. ELDER	A. H. BELL
RALPH E. ESAREY	COLEMAN D. HUNTER	S. A. BERTHIAUME
FENTON H. FINN	ROBERT C. LAFFERTY, JR.	G. P. CRAWFORD
JOHN W. INKSTER	D. J. MUNROE	R. J. CULLEN
GRAHAM B. MOODY	T. F. PETTY	W. S. MCCABE
CHARLES H. ROW	GLENN C. SLEIGHT	E. L. REED, JR.
	PAUL H. UMBACH	R. M. WILSON
	C. W. WILSON	

DISTINGUISHED LECTURE COMMITTEE

FRED H. MOORE (1949), *chairman*, Magnolia Petroleum Company, Roswell, New Mexico

1948	1949	1950
EVERETT F. STRATTON	HUGH R. BRANKSTONE	W. J. HILSEWECK
CARROLL M. WAGNER	JOHN L. FERGUSON	H. T. MORLEY

SPECIAL COMMITTEES

COMMITTEE ON BOY SCOUTS LITERATURE

FRANK GOUIN, *chairman*, Box 208, Duncan, Oklahoma

A. C. BACE	DON L. CARROLL	G. W. PIRTLE
MAX W. BALL	C. L. COOFER	W. T. THOM, JR.
HAL P. BYBEE	CAREY CRONEIS	RUSSELL M. TRIPP
	E. C. DAPPLES	

EDUCATION COMMITTEE

ROY R. MORSE, *chairman*, Shell Oil Company, Box 2099, Houston, Texas

STUART K. CLARK	RONALD K. DEFORD	THERON WASSON
MORGAN J. DAVIS	HENRY V. HOWE	

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa 1, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

Charles William Alcock, Jackson, Miss.
Knight K. Spooner, Castle J. C. Harvey, Jules Braunstein

James C. Bransford, Los Angeles, Calif.
Vernon L. King, Harold H. Sullwold, Jr., William Ross Cabeen

Lou G. Cornish, Lafayette, La.
G. H. Westby, Robert Baum, A. J. Barthelmes

Kazim Ergin, Ankara, Turkey
Cevat Tasman, Beno Gutenberg, John P. Buwalda

Charles Merwin Gilbert, Berkeley, Calif.
George D. Louderback, Theo. H. Crook, Carlton D. Hulin

Edward Walter Hans, San Antonio, Tex.
C. D. Whitsitt, W. Harlan Taylor, L. O. Seaman

Edward Willis Harrington, Mt. Vernon, Ill.
John B. Patton, Thomas E. Wall, E. E. Rehn

Alfred John Haworth, New York, N. Y.
A. F. Bateman, Jr., V. C. Illing, Walter S. Olson

Ernest B. Hill, Corsicana, Tex.
George H. Clark, S. A. Berthiaume, I. K. Nichols

Mervin Richard Hundley, San Antonio, Tex.
C. D. Whitsitt, Frank R. Kittredge, G. D. Gibson

Wassef Iskander, Cairo, Egypt
O. A. Seager, G. C. F. Greant, D. B. Eicher

Peter Jacobsen, Jr., Caracas, Venezuela, S. A.
G. Zuloaga, K. F. Dallmus, H. W. Thoms

Christian Jensen, Houston, Tex.
Leo R. Newfarmer, F. A. Nelson, A. E. Smith

Byron Kenneth Johnson, Morgan City, La.
Castle J. C. Harvey, W. Dow Hamm, B. M. Choate

Ole Herman Kristofferson, Mount Pleasant, Mich.
Kurt H. de Cousser, Rex P. Grant, Edward J. Baltrusaitis

Heinz A. Lowenstam, Urbana, Ill.
Alfred H. Bell, M. M. Leighton, William E. Ham

T. A. Manhart, Tulsa, Okla.
G. H. Westby, A. J. Barthelmes, Joseph E. Morero

Warren D. Mateer, Stillwater, Okla.
R. V. Hollingsworth, Harold L. Williams, H. A. Ireland

Hans Norbisrath, Bellingham, Wash.
William E. Wallis, Walter C. Warren, Harold E. Vokes

Caswell Silver, Pagosa Springs, Colo.
Vincent C. Kelley, Robert E. Murphy, Parry Reiche

Robert Franklin Van Cleave, Maplewood, La.
W. Dow Hamm, O. C. Clifford, Jr., B. M. Choate

William Carlton Weaver, Corpus Christi, Tex.
Ira H. Stein, Dale L. Benson, O. G. McClain

FOR ASSOCIATE MEMBERSHIP

Robert Henry Abott, Jr., Houma, La.
Shapleigh G. Gray, C. H. Sample, A. F. Childers, Jr.
Willis Howard Alderman, Wichita Falls, Tex.
V. E. Monnett, Keith M. Hussey, Carl A. Moore
Luis Antonio Baldo, Caracas, Venezuela, S. A.
J. Harlan Johnson, W. S. Levings, F. M. Van Tuyl
Richard Carl Banister, Tulsa, Okla.
A. N. Murray, Constance G. Eirich, W. B. Wilson
Burl J. Boring, Ponca City, Okla.
William A. Kelly, Rex P. Grant, Glenn C. Clark
Charles Spencer Brown, Great Bend, Kan.
W. F. Bowser, Fred G. Phelps, T. A. Clote
Alcott B. Cox, Jr., Shreveport, La.
Paul B. Fahle, W. E. Wallace, Wilton W. LaRue
Patricia Jean Douglas, Los Angeles, Calif.
K. O. Emery, D. A. McNaughton, H. R. Gale
Jack Gordon Elam, Long Beach, Calif.
James Gilluly, Cordell Durrell, M. N. Bramlette
James Clifford Freeman, Boulder, Colo.
Warren O. Thompson, John R. Hayes, W. E. Belt, Jr.
Lyman Edgar Galbraith, Oklahoma City, Okla.
John Janovy, Kenneth K. Landes, Lewis B. Kellum
Mona Dennis Guiler, Houston, Tex.
W. M. Rust, Jr., A. P. Wendler, J. A. Brooks, Jr.
Norbert Michael Hannon, Jr., Denver, Colo.
J. Harlan Johnson, W. S. Levings, F. M. Van Tuyl
Charles Milby Hartwell, Oil Hill, Kan.
George F. Berry, Jr., L. E. Patterson, Jr., L. G. Morgan
William Plato Harvey, Macomb, Ill.
Eugene McDermott, Cecil H. Green, Edwin D. Gaby
Louis Otto Heintz, Los Angeles, Calif.
E. K. Soper, W. S. Knouse, Emil Kluth
Charles Warren Hunt, III, Bakersfield, Calif.
J. H. Beach, L. W. Saunders, R. S. Beck
Weldon C. Julander, Salt Lake City, Utah
A. C. Trowbridge, A. K. Miller, Garland Peyton
Deane Earle Kilbourne, Lansing, Mich.
William A. Kelly, Gerald E. Eddy, Rex P. Grant
Gordon Henry Killick, Calgary, Alta., Canada
W. C. Howells, H. H. Beach, E. H. Hunt
Robert Matheson Norris, Los Angeles, Calif.
U. S. Grant, E. K. Soper, M. N. Bramlette
George Jordan Petsoff, Jr., Tulsa, Okla.
A. J. Barthelmes, G. H. Westby, Robert Baum
Forest Bovaird Rees, Tulsa, Okla.
A. N. Murray, C. V. Millikan, Carroll V. Sidwell
Carroll Norton Roberts, Indianapolis, Ind.
Ernest Rice Smith, Harold R. Wanless, Raymond C. Gutschick

Richard W. Rush, Austin, Minn.
Norman D. Newell, Marshall Kay, Robert L. Sielaff
Norman Alfred Sax, Boulder, Colo.
Warren O. Thompson, John R. Hayes, W. Warren Longley
James Alexander Shields, Caracas, Venezuela, S. A.
Frank L. LeRoy, Norman E. Weisbord, F. I. Martin
Theodor Sorgenfrei, Copenhagen, Denmark
Hilmar Odum, C. W. Flagler, Albert Gregersen
Betty Jean Stark, Gainesville, Tex.
Gayle Scott, E. A. Vogler, W. M. Winton
Felix Vendilion Vinklarek, Houston, Tex.
A. G. Nance, L. P. Bristley, Jr., Hal P. Bybee
Richard Atlee Wise, Caracas, Venezuela, S. A.
Albert J. Z. Caan, P. P. Conrad, Norman E. Weisbord

FOR TRANSFER TO ACTIVE MEMBERSHIP

Louis Willard Goudy, Oklahoma City, Okla.
Ervin L. Selk, Ben F. Baldwin, George H. Galloway
Jack Martin, Houston, Tex.
I. M. Griffin, Jr., Chester Sappington, T. O. Hall
Roy A. Payne, Houston, Tex.
W. R. Farley, George N. May, B. M. Choate
Raymond William Snyder, Midland, Tex.
H. C. Vanderpool, John M. Clayton, Raymond A. Stehr
Robert Masterman Stainforth, Talara, Peru, S. A.
Lorne A. Smith, H. H. Suter, K. W. Barr
M. Hall Taylor, Jr., New York, N. Y.
Marshall Kay, Raymond C. Moore, Charles H. Behre, Jr.
Harry Allison Tourtelot, Lost Cabin, Wyo.
D. L. Blackstone, Jr., George R. Downs, Robert L. Sielaff

(*Continued on page 1708*)

SUPPLEMENTARY MEMBERSHIP LIST, SEPTEMBER 1, 1947

Members	97
Associates	147
	244

Total additions since publication of list of March *Bulletin*

Abel, Walter D., Div. of Corporations, State of Calif., 217 W. First St., Los Angeles, Calif.
Ackley, Kenneth A., Carter Oil Co., Box 568, Mattoon, Ill.
Allen, Arthur Thomas, Jr., Emory University, Emory University, Ga.
‖Allen, Charles Gardner, Standard Oil Co. of Calif., Camp 11-C, Taft, Calif.
‖Allen, Fraser Hall, Stanolind Oil & Gas Co., Tulsa, Okla.
‖Allen, Lynn D., Socony-Vacuum Oil Co. of Venezuela, Apt. 246, Caracas, Venezuela, S. A.
‖Almeida, Luis Alves de, Conselho Nacional do Petroleo, Bahia, Brazil, S. A.
‖Amsden, Edgar A., Stanolind Oil & Gas Co., Box 1092, Shreveport, La.
‖Armstrong, Robert Clark, Skelly Oil Co., 510 Petr. Bldg., Wichita, Kan.
Armstrong, William Burrus, Ohio Oil Co., Thompson Bldg., Tulsa, Okla.
Baillie, Wilfred, Shell Oil Co., Inc., Box 1817, Jackson, Miss.
Bajza, Charles C., Stanolind Oil & Gas Co., Box 40, Casper, Wyo.
Bald, Warren Arthur, Ohio Oil Co., Durango, Colo.
‖Barling, Robert, Cities Service Oil Co., Box 779, Tyler, Tex.
‖Bartlett, Dewey Follett, Keener Oil & Gas Co., 406 Natl. Bank of Tulsa Bldg., Tulsa, Okla.
Bell, Donald, Shell Oil Co., Inc., Box 1509, Midland, Tex.

Beltz, Edward William, 309 Hillside Ave., Douglaston, N. Y.
‖Benson, Morris H., Mid-Continent Petr. Corp., Tulsa, Okla.
Bevan, Arthur Charles, State Geol. Survey, Natural Resources Bldg., Urbana, Ill.
‖Bigger, Morton, Jr., 5941 Averill Way, Dallas, Tex.
Birmingham, Edward Louis, Jr., Bay Petr. Corp., 1006 Brown Bldg., Wichita, Kan.
‖Brahaney, Frank T., Jr., independent, Box 1695, Midland, Tex.
‖Branson, John Wallace, 538½ S. Lahoma, Norman, Okla.
‖Brodek, Ralph E., Western Gulf Oil Co., Bakersfield, Calif.
Brookby, Harry Dudley, Phillips Petr. Co., Bartlesville, Okla.
‖Bryan, John Victor, independent, Box 344, Chickasha, Okla.
‖Buffington, Edwin Couger, Calif. Inst. of Tech., Pasadena, Calif.
Bunch, Rosella Leota, Shell Oil Co., Inc., Box 2037, Tyler, Tex.
Burgl, Hans, Laakirchen, Olling 14, Ob. Ost., Austria
Butticaz, Pierre Hugo, Standard Oil Co. of Morocco, 40 rue des Ouled Ziane, Casablanca, Morocco
Bychok, Victor, The Atlantic Refg. Co., Box 2819, Dallas, Tex.
Cathcart, Stanley H., Pennsylvania Geol. Survey, Harrisburg, Pa.
‖Chakravorty, Sailendra Kumer, 1710 Ford St., Golden, Colo.
Chapman, Robert Mills, U. S. Geol. Survey, Box 1088, Fairbanks, Alaska
Chasteen, Lawrence W., Union Oil Co. of Calif., 617 W. Seventh St., Los Angeles, Calif.
‖Clark, Robey H., Magnolia Petr. Co., Box 1828, Oklahoma City, Okla.
Clayton, John M., Seaboard Oil Co., 1400 Continental Bldg., Dallas, Tex.
Cohn, Arthur A., Jr., The Texas Co., 929 S. Bdwy., Los Angeles, Calif.
‖Coleman, Major Hubert Paul, Student Detachment Artillery School, Fort Sill, Okla.
‖Conrad, Stanley D., Richfield Oil Corp., 560 Haberfelde Bldg., Bakersfield, Calif.
‖Courtney, Chyde Jasper, The Calif. Co., 1818 Canal Bldg., New Orleans, La.
Cowan, Clifton A., Union Oil Co. of Calif., 240 Ricou-Brewster Bldg., Shreveport, La.
‖Cox, William Jones, Jr., Emory University, Emory University, Ga.
‖Craddock, William Percival, Humble Oil & Refg. Co., Baytown, Tex.
Crary, Donald, Sohio Petr. Co., 614 Neils Esperson Bldg., Houston, Tex.
‖Crotty, Burns McCashin, Apt. 11, 707 N. Carrigo, Midland, Tex.
‖Culligan, Leland Bowen, 801 University, Boulder, Colo.
‖Cunningham, James Marvin, State Geol. Survey, Baton Rouge, La.
‖Darnall, Clint Adrian, The Atlantic Refg. Co., Box 2819, Dallas, Tex.
‖Davis, William Warren, Sun Oil Co., Box 2880, Dallas, Tex.
‖De Long, Jack Myler, Stanolind Oil & Gas Co., Box 660, Tyler, Tex.
‖Dewey, Robert Flanders, Apt. 3, 505 E. Boyd St., Norman, Okla.
Doh, Charles A., Schlumberger Well Surveying Corp., Box 571, Mattoon, Ill.
Eley, Jack Burt, Oklahoma Natural Gas Co., Oklahoma City, Okla.
Emrick, Eggleston Byers, consulting, Box 395, Conrad, Mont.
Eyler, Albert Taylor, Jr., Shell Oil Co., Inc., Box 1191, Tulsa, Okla.
‖Fabre, Gilbert, Magnolia Petr. Co., 1704 Alamo Natl. Bldg., San Antonio, Tex.
Ferguson, Kenneth Sears, 1245 Park Row, La Jolla, Calif.
‖Ferris, Bernard Joe, 920 Twelfth St., Golden, Colo.
‖Fickel, Raymond Arnold, Sinclair Prairie Oil Co., Box 1242, Amarillo, Tex.
‖Fogarty, Charles Franklin, Socony-Vacuum Oil Co., Bogota, Colombia, S. A.
Follansbee, George Sherman, Jr., Universal Consolidated Oil Co., Rm. 950, 417 S. Hill St., Los Angeles, Calif.
‖Ford, Glen Melvin, The Texas Co., Box 476, Mattoon, Ill.
‖Foster, Helen Laura, Wellesley College, Wellesley, Mass.
‖Frautschy, Jeffery Dean, U. S. Geol. Survey, Monroe, Wis.
Fuenning, Paul, Geophoto Services, Inc., 305 E. & C. Bldg., Denver, Colo.
Gilkison, Don, Gulf Oil Corp., Box 661, Tulsa, Okla.
Gillingham, William James, Schlumberger Surenco, Apt. 1608, Caracas, Venezuela, S. A.
Gilmore, Robert Beattie, DeGolyer & MacNaughton, 1000 Continental Bldg., Dallas, Tex.
Gist, James T., Pacific Western Oil Corp., Casper, Wyo.
‖Goering, Milford Wayne, Amerada Petr. Corp., Box 2249, Casper, Wyo.
‖Goodell, Horace Nelson, Union Oil Co. of Calif., Box 980, Laramie, Wyo.
Goodrich, Willard Dale, Mid-Continent Petr. Corp., 1103 Mid-Continent Bldg., Tulsa, Okla.
‖Gould, Howard Ross, 505 N. Camino Real, Redondo Beach, Calif.
Graham, Ralph C., Tennessee Gas & Transmission Co., Houston, Tex.
‖Griffin, Robert Harrell, Standard Oil Co. of Texas, 1125 Hamilton Bldg., Wichita Falls, Tex.
‖Griffitts, Mary Oswald, University of Colorado, Boulder, Colo.
‖Grossman, Irving, University of North Dakota, Grand Forks, N. Dak.
Gunby, Merle F., consulting, Apt. 2, 1910 Truxillo, Houston, Tex.

‖Hairgrove, Marvin Ellis, Humble Oil & Refg. Co., Laurel, Miss.
Hamilton, Frederick Jamieson, Imperial Oil Co., 339 Seventh Ave., S.W., Calgary, Alta., Canada
Hammer, Sigmund Immanuel, Gulf Research & Devel. Co., Box 2038, Pittsburgh, Pa.
‖Hargraves, Rolla Eugene, The Superior Oil Co., Box 510, Midland, Tex.
‖Harsveldt, Hessel Murk, 6 Koninginnelaan, Ryswyk (Z.H.), Holland
‖Hayes, Paul Louis, The Capital Co., Los Angeles, Calif.
‖Hayes, William C., Jr., State College, Raleigh, N. Car.
‖Hays, Mack Lawrence, Jr., Humble Oil & Refg. Co., Box 2025, Tyler, Tex.
‖Hedley, Tom David, The Ohio Oil Co., Box 3128, Houston, Tex.
‖Heim, Jean W., Stanolind Oil & Gas Co., Box 591, Tulsa, Okla.
‖Helland, James Hans, 126 Lilac Lane, San Antonio, Tex.
Henker, Warren Max, Tropical Oil Co., Bogota, Colombia, S. A.
‖Henkes, William Conrad, Stanolind Oil & Gas Co., Box 40, Casper, Wyo.
‖Herron, Robert Fremont, Chanslor-Canfield Midway Oil Co., Box H, Fellows, Calif.
Hile, Charles O., consulting, Box 358, Boulder, Colo.
‖Holbert, William Jack, 432 W. Twenty-third St., Houston, Tex.
‖Holcomb, Frank Herman, "Tex" Harvey Oil Co., Magnolia Ferry Rd., Palestine, Tex.
Holt, Richard Dexter, Humble Oil & Refg. Co., Box 1236, Roswell, N. M.
‖Honkala, Fred Saul, University of Michigan, Ann Arbor, Mich.
Horton, Leo V., consulting, Box 522, Mt. Vernon, Ill.
‖House, Robert Arling, Gulf Oil Corp., Box 1150, Midland, Tex.
Howard, Arthur Henry, Chadmore Dene, Gipsy Lane, Wokingham, England
‖Hughes, Margaret Moore, Box 398, Ferndale, Calif.
Hunter, J. C., Jr., Hunter & Hunter, 524 Mims Bldg., Abilene, Tex.
Hurndall, John P., consulting, Suite 610, 811 W. Seventh St., Los Angeles, Calif.
Jackson, John Arthur, Arkansas Fuel Oil Co., 1706 Milam Bldg., San Antonio, Tex.
‖Jackson, Roy Othello, University of Michigan, Ann Arbor, Mich.
Johnson, Carl E., consulting, Box 665, Centerville, Tex.
‖Jensen, Homer, Aero Service Corp., Philadelphia, Pa.
‖Johnson, Harold George, Standard Oil Co. of Texas, Box 247, Falfurrias, Tex.
Johnson, Thomas Jesse, Western Oil Devel. Co., 301 Grant Bldg., Abilene, Tex.
Jones, J. Robert, Shell Oil Co., Inc., Midland, Tex.
‖Jones, Joseph Maxfield, The Capital Co., Whittier, Calif.
‖Jones, Roy Meyrick Price, 1630 Fourteenth Ave., Calgary, Alta., Canada
‖Kehoe, William Dunstone, Humble Oil & Refg. Co., Box 506, Tallahassee, Fla.
Kerr, Vivian Robert, Cummins, Berger & Pishny, 1603 Commercial Standard Bldg., Fort Worth, Tex.
Kidd, Frederick Alexander, Shell Oil Co., Inc., Ottawa, Ont., Canada
‖King, Ted Richard, Oklahoma Geol. Survey, Norman, Okla.
Kirschner, Charles E., Union Oil Co. of Calif., Olympia, Wash.
‖Knapp, Lealand Morley The Superior Oil Co., 506 First Natl. Bank Bldg., Denver, Colo.
‖Knox, Robert John, Sinclair-Wyoming Oil Co., Box 545, Lander, Wyo.
Landis, Sam Wallace, consulting, 927 W. Third St., Long Beach, Calif.
Lane, Joseph Howard, Jr., 5424 Plaza Lane, Wichita, Kan.
Latta, Albert Lloyd, Gulf Oil Corp., Box 661, Tulsa, Okla.
‖Lemmons, Jacob E., The Texas Co., Box 1801, Wichita, Kan.
‖Leonard, Alvin R., U. S. Geol. Survey, University of Kansas, Lawrence, Kan.
‖Lewis, Jean, University of Texas, Box 1834, Univ. Sta., Austin, Tex.
Lohman, Stanley William, U. S. Geol. Survey, 124 New Customhouse, Denver, Colo.
‖Long, Alfred B., Sun Oil Co., Box 3265, Beaumont, Tex.
‖Loudon, Elizabeth Ashe, c/o Stanley Beck, Rm. 3, El Tejon Hotel, Bakersfield, Calif.
Mackintosh, John Attrill, The Texas Co., 902 Jones Bldg., Corpus Christi, Tex.
Mauri, Enrique Tomas, Yacimientos Petroliferos Fiscales, Avda. Roque Saenz Pena 777, La Plata, Buenos Aires, Argentina, S. A.
Maxey, Carl Landram, c/o T. H. McCasland, McCasland Bldg., Duncan, Okla.
Maxey, James Roy, United Geophysical Co., Apt. 1085, Caracas, Venezuela, S. A.
‖McBroom, William Ernest, Union Prod. Co., 917 Hamilton Bldg., Wichita Falls, Tex.
‖McConnell, Andrew Pollock, The Texas Co., Box 1270, Midland, Tex.
‖McCreight, Claude Edgar, Jr., Carter Oil Co., Box 25, Manhattan, Kan.
‖McCulloch, George Glenn, Box 1026, Okmulgee, Okla.
‖McFarlan, Edward, Jr., 1915 Nueces St., Austin, Tex.
McGrath, Patrick Bernard, Richmond Explor. Co., Apt. 93, Maracaibo, Venezuela, S. A.
‖McKeever, John Herbert, Jr., The Calif. Std. Co., 700 Lancaster Bldg., Calgary, Alta., Canada
McMillen, Ralph Eugene, Phillips Venezuelan Oil Co., Apt. 1031, Caracas, Venezuela, S. A.
‖Meyer, Marvin Phillip, Illinois State Geol. Survey, Urbana, Ill.

Michel, Pierre, Regie Autonome des Petroles, 27 rue de la Republique, St. Gaudens, Hte.-Garonne, France
‖Miles, Daniel John, Evergreen Hamlet, Pittsburgh, Pa.
‖Mills, Robert Greenleaf, United Geophysical Co., McCain Hotel Bldg., Gainesville, Tex.
‖Miranda-Ruiz, Leandro, Creole Petr. Corp., Apt. 889, Caracas, Venezuela, S. A.
Monnett, Victor Brown, Oklahoma A. & M. College, Stillwater, Okla.
Morange, Andre Raymond, Regie Autonome des Petroles, St. Gaudens, Hte.-Garonne, France
‖Morris, Ray Clement, Stanolind Oil & Gas Co., Box 2089, Amarillo, Tex.
Nelson, Jean O., consulting, 1147 Milam Bldg., San Antonio, Tex.
Neuschel, Sherman K., U. S. Geol. Survey, Washington, D. C.
‖Newton, Kenneth, Sun Oil Co., Box 1861, Midland, Tex.
Nixon, Earl K., Lindley Hall, Univ. of Kansas, Lawrence, Kan.
Noble, Levi F., U. S. Geol. Survey, Valyermo, Calif.
‖Noon, Theodore Woods, Jr., The Texas Co., Box 600, Wichita Falls, Tex.
‖Norvang, Aksel, Danish-American Prospecting Co., Asanigaarden, Viborg, Denmark
‖O'Bert, Lawrence Kay, Amerada Petr. Corp., Los Angeles, Calif.
‖O'Brien, Francis Eugene, The Ohio Oil Co., 539 S. Main, Findlay, Ohio
‖Osanik, Alec N., Miss. River Comm., Louisiana State University, Baton Rouge, La.
‖Osmond, John Chambers, Jr., Humble Oil & Refg. Co., Box 672, Henderson, Tex.
‖Outlaw, Donald Elmer, 4307 Avenue F, Austin, Tex.
‖Pantin, Jose Henrique, Creole Petr. Corp., Apt. 889, Caracas, Venezuela, S. A.
‖Parker, Travis J., Texas A. & M. College, College Station, Tex.
‖Payne, Bill R., Humble Oil & Refg. Co., Box 506, Tallahassee, Fla.
Payne, Don W., Sinclair Prairie Oil Co., Box 521, Tulsa, Okla.
‖Payne, Roy A., Box 972, Lake Charles, La.
‖Pearson, Carol, Shell Oil Co., Inc., Box 1509, Midland, Tex.
Pearson, Raymond Elliott, Richfield Oil Corp., Box 470, Long Beach, Calif.
Peck, Raymond E., 208 Swallow Hall, University of Missouri, Columbia, Mo.
Perebaskine, Victor, Regie Autonome des Petroles, rue St. Raymond, St. Gaudens, Hte.-Garonne, France
Perry, Robert George, Iraq Petr. Co., Ltd., Haifa, Palestine
‖Petersen, William Arthur, Continental Oil Co., Ponca City, Okla.
Petters, Viktor, Tropical Oil Co., Bogota, Colombia, S. A.
Pierce, C. Brooks, Shell Oil Co., Inc., Central Bldg., Wichita, Kan.
‖Planteroth, Raymond Oscar, The Texas Co., Box 262, Mt. Pleasant, Mich.
‖Poff, HarmanBryan, independent, 2544 Wabash, Fort Worth, Tex.
‖Price, John C., Magnolia Petr. Co., Tyler, Tex.
‖Rabel, Hylda Merle, Arkansas Fuel Oil Co., 1706 Milam Bldg., San Antonio, Tex.
‖Rees, Wesley Waltrip, Magnolia Petr. Co., Box 900, Dallas, Tex.
Renz, Hans Hermann, Cia. de Petroleo Shell del Peru, Lima, Peru, S. A.
Ring, Edgar Raymond, Jr., Colombian Petr. Co., Apt. 100, Cucuta, Colombia, S. A.
Rist, Robert L., Standard Oil Co. of Calif., Box 1200, Bakersfield, Calif.
‖Robinson, Florence Marie, 2120 E. Ivanhoe Pl., Milwaukee, Wis.
‖Rodriquez-E., Guillermo, Creole Petr. Corp., Apt. 889, Caracas, Venezuela, S. A.
‖Rominger, Joseph Franklin, U. S. Geol. Survey, Gen. Del., Vernal, Utah
Rosales-W., Cesar M., The Caribbean Petr. Co., Apt. 19, Maracaibo, Venezuela, S. A.
‖Rozanski, George, Dept. de Petroleo, Apt. 880, Lima, Peru, S. A.
‖Russell, Randall Wayne, Box 62, McCamey, Tex.
‖Savoy, Basil Victor, 902 N. Broadway, Salem, Ill.
‖Schieck, Emmett E., Sohio Petr. Co., Box 359, Casper, Wyo.
Schiflett, Hubert Lee, 521 N. Crockett St., Sherman, Tex.
Schneegans, Daniel, Institut du Petrole, 2 Rue de Lubeck, Paris, France
‖Scholl, Milton Richard, Jr., 2604 Guadalupe, Austin, Tex.
Simmons, Fred E., Jr., Louisiana Land & Explor. Co., Houma, La.
‖Skrabanek, John Warren, University of Texas Lands, Box 1663, Midland, Tex.
‖Sleeper, James L., Jr., The Texas Co., Box 1270, Midland, Tex.
‖Sloan, William W., Jr., Carter Oil Co., Box 1739, Shreveport, La.
Smith, Frederick A., Sohio Petr. Co., Box 1539, Lake Charles, La.
‖Smith, Robert Maurice, The Superior Oil Co., 2211 Apco Tower, Oklahoma City, Okla.
‖Smythe, John Archibald, The Texas Co., Box 405, Shelby, Mont.
‖Snider, James Wilson, Amerada Petr. Corp., Box 591, Midland, Tex.
‖Sollero, Camillo Soares, Conselho Nacional do Petroleo, Bahia, Brazil, S. A.
‖Soper, Emmet Harland, The Texas Co., Box 405, Shelby, Mont.
Spencer, Jesse Emory, Tucker Explor. Co., Box 2089, Casper, Wyo.
Sprinkel, Robert Lee, Jr., Shell Oil Co., Inc., Box 691, Ventura, Calif.

Starnes, Jasper Leon, 3702 Bailey Lane, Austin, Tex.
Story, James Richard, Cities Service Oil Co., Odessa, Tex.
Story, Richard Franklin, Shell Oil Co., Inc., Box 5157, Drew Sta., Lake Charles, La.
Stulken, Edgar John, Geophysical Service, Inc., Dallas, Tex.
Tator, Benjamin Almon, Louisiana State University, University, La.
Taylor, Louis, Richfield Oil Corp., El Monte, Calif.
Thomas, Chester Reams, Corporacion de Fomento, Punta Arenas, Chile, S. A.
Thomas, Joseph Wayne, Plymouth Oil Co., Sinton, Tex.
Thomason, Ben R., Jr., The Texas Co., Box 1270, Midland, Tex.
Thompson, Raymond James, Gulf Oil Corp., Houston, Tex.
Toland, David R., Carter Oil Co., Box 191, Roosevelt, Utah
Trimmell, John A., Black-Marshall Oil Co., 1910 Broadway, Great Bend, Kan.
Turner, Roy Wilbur, Tide Water Assoc. Oil Co., 308 Hopkins Bldg., Bakersfield, Calif.
Turpin, Evelyn Marie, Pure Oil Co., Box 1398, Billings, Mont.
Underwood, George Woods, Mene Grande Oil Co., C.A., Apt. 45, Barcelona, Venezuela, S. A.
van Bellen, Robert Carel, Syrian Petr. Co., Aleppo, Syria
Vander Hoof, Vertress Lawrence, Stanford Univ., Stanford University, Calif.
Van Houten, Franklyn Bosworth, Princeton University, Princeton, N. J.
Verastegui-Mac Kee, Pedro, Zorritos Oil Field, Zorritos, Peru, S. A.
Vickers, Robert Brice, Jr., Texas Pacific Coal & Oil Co., Breckenridge, Tex.
Vittrup, Lawrence J., The Texas Co., Box 2332, Houston, Tex.
Volk, Henry William, Jr., Tide Water Assoc. Oil Co., Corpus Christi, Tex.
Wagner, Holly Clyde, 205 W. One hundred fifteenth St., Los Angeles, Calif.
Wallace, William Harry, Jr., La Gloria Corp., Corpus Christi, Tex.
Wallis, Frederick Bradley, The Texas Co., Galveston, Tex.
Wang, Kia-Kang, Louisiana State University, Baton Rouge, La.
Warren, John Henry, Okla. Geol. Survey, Norman, Okla.
Weaver, Oscar David, Jr., 703-B W. Twenty-third, Austin, Tex.
Webb, John Benwell, Imperial Oil, Ltd., 339 Seventh Ave., W., Calgary, Alta., Canada
Weller, Arthur Reilly, Shell Oil Co., Inc., Box 999, Bakersfield, Calif.
Wible, Everest Elmer, Bell Bros., Robinson, Ill.
Williams, Milton, 2240 North Boulevard, Houston, Tex.
Wise, Blanche Lorraine, U. S. Geol. Survey, Denver, Colo.
Wood, Alexander Wayne, Phillips Petr. Co., Box 708, Bartlesville, Okla.
Woollett, LeRoy Andrew, Jr., 1132 W. Woodlawn Ave., San Antonio, Tex.
Yee, Bing Quai, 505 Chautauqua St., Norman, Okla.
ZoBell, Claude E., Scripps Inst. of Oceanography, La Jolla, Calif.
Zoller, Victor Hubert, The Chicago Corp., Box 1047, Shreveport, La.
Zwald, Edwin Arnold, Union Prod. Co., Box 711, Beeville, Tex.

REPORT OF NOMINATING COMMITTEE

Dallas, Texas, July 22, 1947

To the Executive Committee
Carroll E. Dobbin, Chairman:

In accordance with Art. IV, Sec. 2, of the Constitution, your nominating committee presents the following slate of candidates for officers of the Association for the year 1948. Each nominee has expressed his willingness to serve.

For President—PAUL WEAVER, Gulf Oil Corporation, Houston, Texas
For Vice-President—ROY M. BARNES, Continental Oil Company, Los Angeles, California
For Secretary-Treasurer—J. V. HOWELL, consulting geologist, Philtower Building, Tulsa, Oklahoma
For Editor—CLARENCE L. MOODY, The Ohio Oil Company, Shreveport, Louisiana

Respectfully submitted, FREDERIC H. LAHEE, *chairman*
O. L. BRACE, M. GORDON GULLEY, HAROLD W. HOOTS, L. MURRAY NEUMANN

Note.—The photographs and biographies of candidates for officers of the Association for the year 1948 will be published in the November *Bulletin*, provided they are received at Association headquarters not later than October 15.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 31, NO. 9 (SEPTEMBER, 1947), PP. 1698-1702, 2 FIGS.

MEMORIAL

FREDERICK BYRON PLUMMER
(1886–1947)

Frederick Byron Plummer, born August 31, 1886, Hanover, New Hampshire, died suddenly of a heart attack, near San Marcos, Texas, February 17, 1947. Of Scottish or English origin, the American Plummers are believed to be descendants of Francis Plummer, who came to Newbury, Massachusetts, about 1633. Frederick Byron was the son of Alvah A. and Laura E. Merrill Plummer and was of the tenth or eleventh generation of his family in New England. For more than a century the Plummers have lived in New Hampshire and for most of it in or near Hanover.

Plummer graduated, B. S., Dartmouth College, 1909. He was an assistant in the department of geology, University of Chicago, 1909–11; instructor in geology, Vassar College, 1911–13; and a fellow in geology, University of Chicago, 1913–15. In his graduate work at Chicago he completed practically all requirements except the thesis for his doctor's degree.

His earliest geological work was done in the White Mountains. During the summer of 1914 he was a field assistant in the iron-ore districts of north-central Wisconsin for the Wisconsin Geological and Natural History Survey.

While still at Chicago, Plummer was engaged by Richard A. Conkling, chief geologist for the Roxana Petroleum Company of Oklahoma, and beginning about the middle of 1915 he worked as a field geologist in that state. In early May, 1916, with Clarence E. Hyde, he was transferred to the Houston office of the Roxana and spent some months in investigations on the Gulf Coast and in East Texas. In the early winter of 1916 he moved to North Texas with headquarters at Mineral Wells and took charge of mapping the northern part of the Pennsylvanian outcrops. He gave a preliminary report on this work at the Dallas meeting of the Association in March, 1919. At that time Wallace Pratt said of the work, "most of us in North Texas believe the Roxana Petroleum Company is doing the most thorough, the most extensive geological work of any of us." Plummer was congratutulated upon this paper by Charles Schuchert and David White. The final report, "Stratigraphy of the Pennsylvanian Formations of North-Central Texas," was published in 1921 under the joint authorship of Plummer and Raymond C. Moore. Plummer was in charge of geological work for Roxana in Texas and Louisiana from 1917 to 1920.

From late 1920 until late 1922, Plummer was a member of the headquarters staff of geologists for the Royal Dutch-Shell group at The Hague. Upon his return to the United States he continued with the Roxana until late October, 1923, when he joined the Rycade Oil Corporation, chief geologist, Donald C. Barton, as a field geologist. He continued in this position, except for leaves during the spring quarter of each year, until the end of 1925. His first assignment was a reconnaissance examination of the petroleum prospects of Maverick County. From early December, 1923, until early November, following, he mapped in detail the fault-line area extending northward from Mexia and then spent several months in the Red River area. The writer had the pleasure of a field trip with Plummer upon the completion of this work, in order to be shown the criteria on which his zoning of the Midway was based. From July, 1925, until mid-September, Plummer studied West Texas, including the trans-Pecos region. The rest of the year was spent completing gaps in his fault-line work.

Plummer spent the entire year of 1926 as chief geologist in Texas and New Mexico of the Amerada Petroleum Corporation, reporting directly to John Lovejoy. In 1927 and

1928 he was a consulting geologist to the Vacuum Oil Company, engaged in interpreting in geological terms, on a regional basis, and with valuable results, torsion-balance and magnetic surveys in the Permian basin.

He joined the Bureau of Economic Geology of the University of Texas in November, 1928, and continued to work with that Bureau until his death. As a geologist, his outstanding achievements were his masterful summary, including much original work, of the Cenozoic system of Texas which makes up a third of Volume I of *The Geology of Texas*. His study

FREDERICK BYRON PLUMMER

of the Pennsylvanian of Texas has been noticed. Of like importance are his studies of the Carboniferous formations of the Llano uplift, much of which is yet to be published.

Plummer was largely responsible for the establishment of a department of petroleum engineering at the University of Texas. Beginning with the 1928–29 session, the University offered a course leading to the Bachelor of Science degree in petroleum production engineering. The course was catalogued to be given by Professor E. H. Sellards but it is Dr. Sellards' recollection that he taught the course only for about a month before Plummer

arrived. In 1930 a department was organized with Plummer as chairman and full professor. He offered two courses, one in petroleum production methods and another in oil-field management. Plummer continued this chairmanship until he was succeeded by Harry Power in the autumn of 1936 and he continued his professorship in the school, including membership in the graduate faculty, until his death.

As a petroleum engineer, Plummer was interested chiefly in research in the areas where the field is overlapped by the sciences of chemistry and geology. His chief accomplishments were his studies of the waters of the Woodbine sand and as a teacher. He published a series of fifty-odd articles on the fundamentals of petroleum engineering in the *Oil and Gas Journal* during 1944–45.

Plummer became a member of the American Institute of Mining and Metallurgical engineers in 1917, of this Association in 1919, of the Institute of Petroleum (London) in 1922, and a fellow of the Geological Society of America in 1925. He was a founder of the Society of Economic Paleontologists and Mineralogists and it was chiefly through his efforts that the five-thousand-dollar fund was raised in 1926 which made the publication of its journal possible. He was secretary of the Society in 1927–29 and secretary-treasurer in 1930.

He was a member and one-time president of Sigma Xi at the University of Texas, president of the Texas Academy of Science, 1945–46, a fellow of the American Geographical Society, some-time secretary and national president of Phi Eta, a member and founder of Pi Epsilon and a member of Sigma Gamma Epsilon and Phi Kappa Tau.

He was a lecturer in petroleum geology at the University of Chicago during the spring quarters of 1924, 1925, and 1926 and at Northwestern University, 1929–1932.

From August to September, 1938, Plummer did geological work in Santo Domingo for Harold C. Bishop. He spent most of the last half of 1946 in geological studies of the Maranhao basin, northern Brazil, for the Conselho Nacional do Petroleo.

In 1918 Plummer married Helen Jeanne Skewes, who had been an office geologist with the Illinois Geological Survey, 1914–17, and with the Roxana Petroleum Company, 1917–18. Mrs. Plummer is an able geologist and eminent paleontologist in her own right and one of the pioneers in the field of micropaleontology.

Fred Plummer, geologist, paleontologist, and petroleum engineer, was a friendly man of wide interests and inquiring mind, a tireless worker and prolific writer. He ranks with those other New Englanders, Donald Barton and Sidney Powers, in his outstanding contributions to petroleum geology and to the science of geology. He is among the top half dozen men to whom we are indebted for our present comprehensive knowledge of the geology of the state of Texas.

E. DEGOLYER

Dallas, Texas
June 19, 1947

MICHAEL MARCUS VALERIUS
(1872–1947)

Michael Marcus Valerius was born in Sigourney, Iowa, January 16, 1872, the son of Peter and Emma Valerius. After graduating from Sigourney High School, he took up the study of commercial law but, before completing the course, became interested in dramatic art and traveled until 1898. He graduated in pharmacy from Drake Univeristy in September, 1901, and soon after engaged in the drug business with his uncle, George Valerius, in Hoisington, Kansas. From 1905 to 1907, he was vice-president and general manager of the Hoisington Oil and Gas Company which operated in Miami County, Kansas. He married Miss Ina M. Brinton of Stuart, Iowa, on October 21, 1903, and they moved to Florence, Kansas, in 1907, where he was associated with Ed O'Brien, of Trapshooter fame.

Mrs. Valerius died on January 5, 1908, after which Mr. Valerius engaged in farming at Stuart, Iowa, until 1909, at which time he went to Sutherlin, Oregon, where he was engaged in coal mining and orchards. He returned to Kansas in 1910 to engage in drilling operations in the oil and gas fields of the eastern part of the state. During 1911 and part of 1912, he examined oil and gas prospects in Oklahoma, Arkansas, Louisiana, and Texas.

MICHAEL MARCUS VALERIUS

Realizing the value of applied geology in oil and gas explorations, he entered the Missouri School of Mines for a special course in field geology. Upon completion of the course in 1913, Mr. Valerius induced Professor V. H. McNutt to join him in forming one of the pioneer firms of consulting geologists in the Mid-Continent. Offices were established in the old Clinton Building in Tulsa.

In 1914 the firm was joined by V. H. Hughes. The new firm of Valerius, McNutt and Hughes engaged in general consulting practice until its dissolution in 1919. In addition to the general practice in the Mid-Continent, branch offices were opened, first in Billings, Montana, and later in Lexington, Kentucky.

During 1919 and part of 1920, Mr. Valerius devoted the greater part of his time to the management of the Trapshooters Oil Company, with operations chiefly in Kansas. After returning to Tulsa in 1920 and again engaging in general consulting work, he organized the M. M. Valerius Oil and Gas Company. One of the first ventures of the new company was the drilling of a test on the Fairport anticline in the northwestern part of Russell County, Kansas. The completion of this test as a commercial producer opened the western half of Kansas as probable oil and gas territory. Prior to the completion of this well, western Kansas was generally regarded as highly improbable oil and gas territory.

After opening the Russell County field, the M. M. Valerius Company sought new fields for exploration. It became one of the pioneer prospectors in the Oklahoma Panhandle and in southwestern Kansas. Geologic investigations were carried on in other undeveloped areas. Several years after its inception, the M. M. Valerius Company was sold. Mr. Valerius continued to operate as an individual until about 1935, at which time he retired to his ranch home on Spavinaw Creek south of Jay, Oklahoma.

Mr. Valerius was a member of A. F. and A. M., Scottish Rite, Mystic Shrine, Eastern Star, and I. O. O. F. He manifested great interest in matters of good citizenship, being a member of the Lions Club, Chamber of Commerce, and Ozarks Playground Association. He was a member of the American Institute of Mining and Metallurgical Engineers, American Mining Congress, American Association of Petroleum Geologists, and the Tulsa Geological Society. During World War I, he was an associate member of the Naval Consulting Board. After completion of the Grand River Dam, he was for a time a director of the Grand River Dam Authority.

Mr. Valerius died, January 18, 1947, at Shreveport, Louisiana. He is survived by a son, Claude N. Valerius, at present division geologist for the Barnsdall Oil Company at Shreveport.

Val, as he was familiarly known, was one of the pioneer geologists of the Mid-Continent. He, and a small group of other geologists, entered the field when petroleum geology was practically an unknown science and was looked upon with skepticism and disdain. To the efforts and accomplishments of that small group, petroleum geology owes a very large debt.

V. H. HUGHES

Tulsa, Oklahoma
June 24, 1947

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 31, NO. 9 (SEPTEMBER, 1947), PP. 1703-1708

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

G. H. CROWL has left Pennsylvania State College to become acting head of the department of geology at Ohio Wesleyan University, Delaware, Ohio.

R. C. GUTSCHICK has resigned as geologist with the Gulf Oil Corporation at Oklahoma City, to become assistant professor in the division of geology at the University of Notre Dame, Indiana.

WILLIAM W. RAND is employed by the Union Oil Company of California, Santa Barbara, California.

A. EDWARD WHEELER has completed graduate work at the University of California at Los Angeles, and is employed by the Shell Oil Company as micropaleontologist at Long Beach, California.

EARL B. NOBLE talked on "Availability of Oil Supplies" at a meeting of the Pacific Northwest Advisory Board, a group representing railroad interests, at Tacoma, Washington, June 27.

The executive committee of the Association met at Cody, Wyoming, August 4, during the field conference of the Geological Society of America and the Wyoming Geological Association. Members in attendance were: President C. E. DOBBIN, of Denver; past-president EARL B. NOBLE, of Los Angeles; vice-president GEORGE H. BUCHANAN, of Houston, and editor CLARENCE L. MOODY, of Shreveport.

CLARENCE P. DUNBAR, formerly director of Classified Personnel and associate director, Bureau of Educational Research, Louisiana State University, Baton Rouge, Louisiana, has been appointed director, Bureau of Institutional Research, University of Louisville, Louisville, Kentucky.

WILLIAM M. MCGILL, assistant State geologist of Virginia since 1929, has been appointed State geologist of Virginia, effective September 1, 1947, to succeed ARTHUR BEVAN, resigned.

JOHN A. BARNETT, for the past 10½ years petroleum engineer with the Oil and Gas Division, Conservation Branch, United States Geological Survey, at Roswell, New Mexico, has resigned to engage in consulting geological work and general oil development operations. His office is Room 6, Ramona Building, and he may be addressed, Box 1128 Roswell, New Mexico.

JAMES G. WHITE resigned, May, 1947, from the Standard Oil Company of Egypt, S.A., to accept a position in the exploration department of the Humble Oil and Refining Company, Corpus Christi, Texas.

SOLON W. STONE of Meadville, Pennsylvania, a teaching fellow at Harvard University, has been appointed instructor in geology at Trinity College, Hartford, Connecticut.

JAMES D. PATE, of the Republic Natural Gas Company, Oklahoma City, Oklahoma, addressed the Oklahoma City Geological Society, August 14, on "The Geology of Cotton County, Oklahoma."

SOUTH TEXAS REGIONAL MEETING
SAN ANTONIO, NOVEMBER 5–6, 1947

A regional meeting of the American Association of Petroleum Geologists, which will be sponsored by the South Texas Section, will be held in San Antonio, Texas, on November 5 and 6, 1947, with the Plaza Hotel as headquarters.

Morning and afternoon technical sessions will be held on Wednesday, November 5, and Thursday, November 6. These technical sessions will be devoted to the presentation of papers on outstanding oil fields, stratigraphic features, and the future possibilities of the Southwest Texas region. Field trips are tentatively being planned for Friday, November 7, and Saturday, November 8, after the technical sessions are completed.

The Plaza Hotel can not accommodate the entire attendance anticipated but transfers of reservations to the Gunter and other San Antonio hotels will be arranged. THORNTON DAVIS in the Alamo National Bank Building in San Antonio is chairman of the hotel committee and all requests for reservations should be addressed to him. Further notice will be sent to members of the A.A.P.G. in regard to the program of the meeting, field trips, and the method of making hotel reservations. ROBERT N. KOLM, Atlantic Refining Company, 1742 Milam Building, San Antonio, is chairman of arrangements.

PACIFIC SECTION ANNUAL MEETING
PASADENA, NOVEMBER 6–7, 1947

The 24th annual meeting of the Pacific Section of the Association will be held at the Huntington Hotel, Pasadena, California, November 6 and 7. HARVEY W. LEE, Union Oil Company of California, Los Angeles, is general chairman.

EASTERN INTERIOR REGIONAL MEETING
ST. LOUIS, JANUARY 14–15, 1948

The Illinois Geological Society and the Indiana-Kentucky Geological Society are sponsoring the Association regional meeting at St. Louis, Missouri, January 14–15, 1948. The Jefferson Hotel is headquarters. The general chairman is E. E. REHN, Sohio Petroleum Company, Box 537, Mt. Vernon, Illinois. The technical program chairman is STANLEY G. ELDER, Sun Oil Company, Evansville, Indiana. Members will be advised about the proper method to make hotel reservations.

The American Association for the Advancement of Science will hold its 114th meeting December 26–31, 1947, at Chicago, Illinois.

The Geological Society of America will hold its annual meeting on December 29, at the Chateau Laurier, Ottawa, Canada.

J. J. HOWARD can now be reached with the following address: Creole Petroleum Corporation, Apartado 889, Caracas, Venezuela.

LAWRENCE K. MORRIS is supervisor for the United Geophysical Company for South America south of the equator. His address is United Geophysical Company, S. A., Rua Uruguaiana 118–9°, Rio de Janeiro, Brazil.

E. P. NEAL, for several years district geologist for the Tide Water Associated Oil Company at Wichita, Kansas, has succeeded J. M. CLARK, recently resigned, as district geologist in the Tulsa area.

JACK L. HOUGH has left the Woods Hole Oceanographic Institution. He may be addressed at the department of geology, University of Illinois, Urbana.

FRED M. HAASE is associated with Moore Brothers, independent geologists and producers, with headquarters in Midland, Texas.

ROBERT JOHN HAMILTON, formerly with the Shell Oil Company of Canada, is in the employ of the Ontario Department of Mines, Queens Park, Ontario, Canada.

A. G. UNKLESBAY has left the geology department at Colgate University, Hamilton, New York, to go to the department of geology at the University of Missouri at Columbia, Missouri.

JACK W. KNIGHT is no longer with The Texas Company, having joined the British-American Oil Company at Los Angeles, California.

AMOS SALVADOR recently with the Mene Grande Oil Company, Caracas, Venezuela, is now at Stanford University, California.

JAMES R. HAMILTON has left the Standard Oil Company of Texas and is now with the La Gloria Corporation, Corpus Christi, Texas.

CHARLES L. LAKE, recently with the Tide Water Associated Oil Company is chief geologist of the Texas Gulf Oil Company at Houston, Texas.

ALBERT CLIVE MENDELSOHN, consulting geologist of Brighton, Sussex, England, is staying in California at 614 North Rodeo Drive, Beverly Hills.

KENNETH PHELPS MCLAUGHLIN has left the School of Geology at Louisiana State University, Baton Rouge. He is at the State College of Washington, Pullman, Washington.

GENE O. DAVIS has resigned his position as geologist for the Skelly Oil Company to work for the Sinclair Prairie Oil Company, geological department at Shreveport, Louisiana.

CHARLES H. SUMMERSON, formerly at the Missouri School of Mines at Rolla, is assistant professor in the department of geology at the Ohio State University, Columbus, Ohio.

G. R. PIERCE has left the employ of the International Ecuadorean Petroleum Company at Ambato, Ecuador, to join the Departmento de Geologica of the Tropical Oil Company at Bogota, Colombia.

T. S. LOVERING has changed his address, effective November 1, from the University of Michigan to the department of geology, University of Arizona, Tucson, Arizona.

PEDRO J. BERMUDEZ, recently with the Standard Oil Company of Cuba, has been transferred to the Creole Petroleum Corporation, Caracas, Venezuela.

B. W. BEEBE has resigned as chief geologist for the Bay Petroleum Company at Denver, to join the Anderson-Prichard Oil Corporation at Oklahoma City, Oklahoma.

RAY A. BURKE, recently at the University of Texas, Austin, is with the Stanolind Oil and Gas Company at Houston, Texas.

JOHN ELIOT ALLEN, chief geologist for the Oregon Department of Geology and Mineral Industries since 1939, has resigned to accept the position of associate professor of geology at Pennsylvania State College, State College, Pennsylvania.

CODY CONFERENCE

J. R. FANSHAWE, General Petroleum Corporation, Casper, Wyoming, conducted the 2-day field trip for the Wyoming Geological Association in the Big Horn basin on August 5 and 6, 1947. There were 259 geologists attending the trip and 82 cars in the caravan. Approximately 87 were Fellows and guests of the Geological Society of America. Approximately 145 were members of the A.A.P.G., including the Executive committee. In addition to the stops and lectures in oil and gas fields, vantage points were chosen to show the structural and stratigraphic problems dealing with rocks from pre-Cambrian successively to the Tertiary and Quaternary.

D. L. BLACKSTONE, JR., University of Wyoming, Laramie, conducted the 1-day field trip from Cody to the Pryor Mountains. There were approximately 100 geologists and 40 cars in the caravan. This trip afforded excellent stops and lectures to deal with the problems of the gravel-covered terraces and methods employed in quarrying to collect vertebrate fossils in Paleocene and Cretaceous outcrops. The visit in the Elk Basin field included a stop at a drilling well where the Madison limestone was being cored with diamond bit.

W. T. THOM, JR., Princeton University and Yellowstone-Bighorn Research Association, conducted a series of shorter trips to the Absaroka volcanic field, to Cedar Mountain, Dead Indian Hill, McCullough Peaks, Ishawooa, and Horse Center anticline. These trips were well attended and aroused interest in a group of problems dealing with structural complexities and stratigraphy.

A. I. LEVORSEN, Stanford University, California, and president of the Geological Society of America, was chairman at a dinner meeting in Cody, on August 4, 1947, whereupon the Rocky Mountain Section of the Society was formally organized. The following officers were installed: president, SAMUEL H. KNIGHT, University of Wyoming; vice-president, N. W. BASS, United States Geological Survey, Denver; secretary, D. L. BLACKSTONE, JR., University of Wyoming.

R. W. MCCANNE, Ohio Oil Company, Casper, president of the Wyoming Geological Association, announces that the composite guide-book for the field conference in the Big Horn basin in limited supply is available to those who were unable to attend. Twenty special papers, maps, stratigraphic sections, well logs, and other illustrations of the Basin geology and oil and gas fields make the book a useful reference. Enthusiasm manifested in this pleasant geological experience augurs well for future joint-enterprises among geological organizations which likewise will attract geologists from all parts of the United States and Canada, from universities, State and Federal surveys, oil and mining companies, the G.S.A., and the A.A.P.G.

T. C. HIESTAND

ADA SWINEFORD has left the Kansas State Geological Survey to join the department of earth sciences at Pennsylvania State College, State College, Pennsylvania.

CLAUDE E. ZOBELL presided as vice-president of Section VI (Soil and Water Microbiology) at the Fourth International Congress for Microbiology in Copenhagen, in August, and received a special citation for "developing the science of marine microbiology and for outstanding work on the effect of bacteria on petroleum hydrocarbons, both of which have found many applications in science and industry during the last ten years."

The State geologists of Illinois, Iowa, Kansas, Nebraska, and South Dakota, with other State scientific representatives and guests, and also Federal and other institutional representatives, attended the Midwest Field Conference in the upper Mississippi Valley region, June 21–28, to study the loess deposits.

RALPH S. JACKSON, associated with the Independent Exploration Company, Houston, since 1932, and vice-president since 1942, resigned, September 15, and has opened an office at Beeville, Texas, to practice as a consulting geophysicist.

ROBERT WOMACK, JR., has resigned from the Gulf Refining Company to become development geologist for The California Company in Mississippi and North Louisiana. He is at Brookhaven, Mississippi.

HARRY D. YOUNKMAN has been with the Sinclair Prairie Oil Company, Tulsa, Oklahoma, during the past five years.

GEORGE W. WHITE on September 1 began his new duties as professor of geology and head of the department at the University of Illinois. Since 1941 he had been professor of geology at Ohio State University and since 1946 State geologist of Ohio.

ADDITIONAL APPLICATIONS APPROVED FOR PUBLICATION

(Continued from page 1693)

FOR ACTIVE MEMBERSHIP

Maxim K. Elias, Lincoln, Neb.
Ronald K. DeFord, C. W. Tomlinson, M. G. Cheney
Ernest Albin Hanson, Roswell, N. Mex.
T. F. Stipp, John A. Barnett, H. S. Cave
Chilton Eaton Prouty, Pittsburgh, Pa.
R. E. Sherrill, A. I. Ingham, Charles R. Fettke
Henry Leonhard Rase, Jr., Shawnee, Okla.
R. B. Ross, E. A. Eckhardt, Louis F. Melchoir
Ray L. Six, Stillwater, Okla.
V. E. Monnett, Charles E. Decker, Robert H. Dott

FOR ASSOCIATE MEMBERSHIP

Sidney McClellan Baker, Kermit, Tex.
J. Harlan Johnson, C. G. Lalicker, W. S. Levings
Charles P. Brocato, Tyler, Tex.
George N. Ely, H. V. Howe, H. N. Fisk
Arnold Charles Chauviere, Baton Rouge, La.
J. Huner, Jr., H. V. Howe, H. N. Fisk
Verne Eugene Farmer, Jr., Rawlins, Wyo.
Jerry R. Kyle, L. T. Hart, James C. McCulloch
Edwin P. Kerr, Jr., Shawnee, Okla.
Carl A. Moore, Keith M. Hussey, Charles E. Decker
Thomas M. McCaul, Jr., Wichita, Kan.
Harold E. McNeil, Walter A. Ver Wiebe, Wendell S. Johns
Donald Arthur Myers, Salt Lake City, Utah
C. C. Church, A. I. Levorsen, Siemon W. Muller
Samuel Aaron Spencer, Kermit, Tex.
Ben H. Parker, W. S. Levings, F. M. Van Tuyl
Richard Sandow Travis, Laramie, Wyo.
William H. Elson, Howard J. Conhaim, James H. Gardner
Thomas H. Walker, Oklahoma City, Okla.
W. L. Moreman, F. E. Wimbish, Bob Hancock
Allan Pavey Watson, Tulsa, Okla.
A. J. Barthelmes, G. H. Westby, Robert Baum

FOR TRANSFER TO ACTIVE MEMBERSHIP

Robert Beall, Tegucigalpa, Honduras
James W. Hunter, Myron A. Dresser, E. F. Schramm
Joseph Bernard Teichman, Wichita, Kan.
V. J. Mercier, M. F. Bear, H. H. Trager
Fred L. Whitney, Shreveport, La.
E. B. Hutson, C. B. Schwartz, L. A. Goebel

PROFESSIONAL DIRECTORY

CALIFORNIA

H. W. BELL
Geologist and Engineer
Consultant in Oil, Gas, Mining
for
Development, Production, Appraisal
5275 Washington Ave., Fresno, Calif.

J. L. CHASE
Geologist — *Geophysicist*
210 Grand Avenue
LONG BEACH 3 CALIFORNIA
Tel. 816-04
Electrical and Magnetic Surveys

HAROLD W. HOOTS
Geologist
555 South Flower
LOS ANGELES 13 CALIFORNIA

LUIS E. KEMNITZER
KEMNITZER, RICHARDS AND DIEPENBROCK
Geologists and Petroleum Engineers
1003 Financial Center Building
704 South Spring Street
LOS ANGELES 14, CALIFORNIA

VERNON L. KING
Petroleum Geologist and Engineer
707 South Hill Street
LOS ANGELES, CALIFORNIA
Vandike 7087

JEROME J. O'BRIEN
Petroleum Geologist
Examinations, Reports, Appraisals
Petroleum Building
714 West Olympic Boulevard
McCARTHY & O'BRIEN Los Angeles 15, Calif.

HENRY SALVATORI
Western Geophysical Company
711 Edison Building
601 West Fifth Street
LOS ANGELES, CALIFORNIA

PAUL P. GOUDKOFF
Geologist
Geologic Correlation by Foraminifera
and Mineral Grains
799 Subway Terminal Building
LOS ANGELES, CALIFORNIA

A. I. LEVORSEN
Petroleum Geologist
STANFORD UNIVERSITY CALIFORNIA

ERNEST K. PARKS
Consultant in
Petroleum and Natural Gas Development
and
Engineering Management
614 S. Hope St.
LOS ANGELES, CALIFORNIA

RICHARD L. TRIPLETT
Core Drilling Contractor
PArkway 9925 1660 Virginia Road
LOS ANGELES 6, CALIF.

COLORADO

C. A. HEILAND
Heiland Research Corporation
130 East Fifth Avenue
DENVER 9, COLORADO

DAN KRALIS
Consulting Geologist
Eastern Colorado
Surface, subsurface, sedimentation, stratigraphy,
paleogeography, wells, reports
Box 1813, Denver, Colorado

HARRY W. OBORNE
Geologist
620 East Fontanero Street
Colorado Springs, Colorado
Main 4711

COLORADO

EVERETT S. SHAW
Geologist and Engineer
3141 Zenobia Street
DENVER 12 COLORADO

V. ZAY SMITH L. BRUNDALL
R. McMILLAN A. R. WASEM
Geophoto Services, Inc.
Photogeologists and Consulting Geologists
305 E & C Building DENVER 2, COLO.

ILLINOIS

C. E. BREHM
Consulting Geologist
and Geophysicist
New Stumpp Building, Mt. Vernon, Illinois

FRANK W. DE WOLF
Consulting Geologist
601 Delaware Avenue
Urbana Illinois

J. L. McMANAMY
Consulting Geologist
Mt. Vernon, Illinois

L. A. MYLIUS
Geologist Engineer
122A North Locust Street
Box 264, Centralia, Illinois

T. E. WALL
Geologist
Mt. Vernon Illinois

INDIANA

HARRY H. NOWLAN
Consulting Geologist and Engineer
Specializing in Valuations
Evansville 19, Indiana
317 Court Bldg. Phone 2-7818

KANSAS

C. ENGSTRAND J. D. DAVIES
Detailed Lithologic Logs
KANSAS SAMPLE LOG SERVICE
415 N. Pershing
Wichita Kansas

WENDELL S. JOHNS
PETROLEUM
GEOLOGIST
Office Phone 3-1540 600 Bitting Building
Res. Phone 2-7266 Wichita 2, Kansas

LOUISIANA

GORDON ATWATER
Consulting Geologist
Whitney Building
New Orleans Louisiana

WILLIAM M. BARRET, INC.
Consulting Geophysicists
Specializing in Magnetic Surveys
Giddens-Lane Building SHREVEPORT, LA.

G. FREDERICK SHEPHERD
Consulting Geologist
123 Maryland Drive
Phone AUdubon 1403 New Orleans 18, La.

MARYLAND

CHALMER L. COOPER
PALEOZOIC
STRATIGRAPHY AND MICROPALEONTOLOGY
705 Bonifant Street Silver Spring, Maryland

MISSISSIPPI

G. JEFFREYS
Geologist *Engineer*
Specialist, Mississippi & Alabama
100 East Pearl Street
Box 2415 Depot P.O.
Jackson, Mississippi

MELLEN & MONSOUR
Consulting Geologists
Frederic P. Mellen E. T. "Mike" Monsour
Box 2571, West Jackson, Mississippi
112½ E. Capitol St. Phone 2-1368

NEW MEXICO

VILAS P. SHELDON
Consulting Geologist and Reservoir Performance Specialist
Geological Reports, Valuations, Appraisals, Microscopic well cutting examination, well completion supervision, reservoir performance analyses
Office Phone 720-W Carper Building
Home Phone 702-J Artesia, New Mexico

NEW YORK

FRANK RIEBER
Geophysicist
Specializing in the development of new instruments and procedures
127 East 73d St. New York 21

BROKAW, DIXON & McKEE
Geologists *Engineers*
OIL—NATURAL GAS
Examinations, Reports, Appraisals
Estimates of Reserves
120 Broadway Gulf Building
New York Houston

BASIL B. ZAVOICO
Petroleum Geologist and Engineer
220 E. 42nd St. City National Bank Bldg.
New York 17, N.Y. Houston, Texas
MUrray Hill 7-7591 Charter 4-6923

NORTH CAROLINA

RODERICK A. STAMEY
Petroleum Geologist
109 East Gordon Street
KINSTON NORTH CAROLINA

R. Merrill Harris Willard M. Payne
HARRIS & PAYNE
Geologists
100 East Pearl Bldg. Phone 4-6286
Jackson, Miss. or L.D. 89

OHIO

JOHN L. RICH
Geologist
General Petroleum Geology
Geological Interpretation of Aerial Photographs
University of Cincinnati
Cincinnati, Ohio

MONTANA

HERBERT D. HADLEY
Petroleum Geologist
Billings, Montana
801 Grand Ave. Phone 2950

OKLAHOMA

GARTH W. CAYLOR
Consulting Geologist
206 Chestnut-Smith Building
624 South Cheyenne Avenue
Tel. 2-1783 Tulsa, Oklahoma

WARREN L. CALVERT
President
The American Exploration Service, Inc.
Core and Stratigraphic Drilling
Elevation and Geologic Service
811 Tradesmens Bank Bldg., Oklahoma City, Okla.

ELFRED BECK
Geologist
308 Tulsa Loan Bldg. Box 33
TULSA, OKLA. DALLAS, TEX.

E. J. HANDLEY
Vice-President
CENTURY GEOPHYSICAL CORPORATION
Phone 5-1171
1333 North Utica Tulsa 6, Okla.

OKLAHOMA

CRAIG FERRIS
Geophysicist
E. V. McCollum & Co.
1510 Thompson Bldg.
Tulsa 3, Okla.

R. W. LAUGHLIN
WELL ELEVATIONS
LAUGHLIN-SIMMONS & CO.
615 Oklahoma Building
TULSA OKLAHOMA

CLARK MILLISON
Petroleum Geologist
Philtower Building
TULSA OKLAHOMA

JOSEPH A. SHARPE
Geophysicist
C. H. FROST GRAVIMETRIC SURVEYS, INC.
4408 South Peoria Ave. Tulsa 3, Okla.

WARE & KAPNER
SAMPLE LOG SERVICE
Wildcat Sample Log Service
Covering Southern Oklahoma
John M. Ware H. H. Kapner
Tulsa, Oklahoma
332 East 29th Place 4-2539

WALTER E. HOPPER
Geologist and Consultant
Petroleum and Natural Gas
Reports Appraisals
Estimates of Reserves
510 National Mutual Building Tulsa 3, Oklahoma

FRANK A. MELTON
Consulting Geologist
Aerial Photographs
and Their Structural Interpretation
1010 Chautauqua Norman, Oklahoma

P. B. NICHOLS
Mechanical Well Logging
THE GEOLOGRAPH COMPANY
25 Northwestern
Oklahoma City Oklahoma

HUGH C. SCHAEFFER
Geologist and Geophysicist
Schaeffer Geophysical Company
National Bank of Tulsa Building
TULSA, OKLAHOMA

G. H. WESTBY
Geologist and Geophysicist
Seismograph Service Corporation
Kennedy Building Tulsa, Oklahoma

ROBERT R. WHEELER
Consulting Geologist
Tekton Oil Co., Inc.
Specializing in Anadarko Basin
Possibilities and Prospects
Phone 7-1142
12th Floor, Petroleum Bldg. Oklahoma City

PENNSYLVANIA

HUNTLEY & HUNTLEY
Petroleum Geologists
and Engineers
Grant Building, Pittsburgh, Pa.
L. G. HUNTLEY
J. R. WYLIE, JR.
JAMES F. SWAIN

TEXAS

JOSEPH L. ADLER
Geologist and Geophysicist
Contracting Geophysical Surveys
in Latin America
Independent Exploration Company
Esperson Building Houston, Texas

GEORGE W. CARR
Carr Geophysical Company
Commerce Building Houston, Texas

TEXAS

IRA A. BRINKERHOFF
Geologist
Associated with
CUMMINS, BERGER & PISHNY
730 Bankers Mortgage Building
Houston, Texas

CHESTER F. BARNES
Geologist and Geophysicist
Petroleum Bldg. P.O. Box 266, Big Spring, Tex.

HART BROWN
BROWN GEOPHYSICAL COMPANY
Gravity
P.O. Box 6005 Houston 6, Texas

JOHN L. BIBLE
Consulting Geophysicist
TIDELANDS EXPLORATION COMPANY
Gravity Surveys on Land and Water
2626 Westheimer
Houston 6, Texas

D'ARCY M. CASHIN
Geologist *Engineer*
Specialist Gulf Coast Salt Domes
Examinations, Reports, Appraisals
Estimates of Reserves
705 Nat'l Standard Bldg.
HOUSTON, TEXAS

PAUL CHARRIN
Geologist and Geophysicist
UNIVERSAL EXPLORATION COMPANY
2044 Richmond Road, Houston 6, Texas
913 Union National Bank Building
Houston 2, Texas

R. H. DANA
Southern Geophysical Company
Sinclair Building
FORT WORTH, TEXAS

CUMMINS, BERGER & PISHNY
Consulting Engineers & Geologists
Specializing in Valuations
1603 Commercial Standard Bldg.
Fort Worth 2, Texas
Ralph H. Cummins
Walter R. Berger
Chas. H. Pishny

E. DEGOLYER
Geologist
Esperson Building
Houston, Texas
Continental Building
Dallas, Texas

ALEXANDER DEUSSEN
Consulting Geologist
Specialist, Gulf Coast Salt Domes
1006 Shell Building
HOUSTON, TEXAS

DAVID DONOGHUE
Consulting Geologist
Appraisals - Evidence - Statistics
Fort Worth National Bank Building
FORT WORTH, TEXAS

J. E. (BRICK) ELLIOTT
Petroleum Geologist
108 West 15th Street Austin, Texas

R. H. FASH
Vice-President
THE FORT WORTH LABORATORIES
Analyses of Brines, Gas, Minerals, Oil, Interpretation of Water Analyses. Field Gas Testing.
828½ Monroe Street FORT WORTH, TEXAS
Long Distance 138

F. JULIUS FOHS
Geologist
433 Esperson Building
Houston 2, Texas
11 E. 44th Street
New York 17, N.Y.

TEXAS

JOHN A. GILLIN
National Geophysical Company
Tower Petroleum Building
Dallas, Texas

JAMES F. GIBBS
Consulting Geologist and Petroleum Engineer
505 City National Bank Building
WICHITA FALLS, TEXAS

SIDON HARRIS
Southern Geophysical Company
1003 Sinclair Building, FORT WORTH 2, TEXAS

CECIL HAGEN
Geologist
Gulf Bldg. HOUSTON, TEXAS

JOHN M. HILLS
Consulting Geologist
Midland, Texas
Box 418 Phone 1015

MICHEL T. HALBOUTY
Consulting Geologist and Petroleum Engineer
Suite 729-32, Shell Bldg.
Houston 2, Texas Phone P-6376

R. V. HOLLINGSWORTH
HAROLD L. WILLIAMS
PALEONTOLOGICAL LABORATORY
Box 51 Phone 2359
MIDLAND, TEXAS

L. B. HERRING
Geologist
Natural Gas Petroleum
Second National Bank of Houston, Houston, Texas

C. E. HYDE
Geologist and Oil Producer
1715 W. T. Waggoner Building
FORT WORTH 2, TEXAS

SAMUEL HOLLIDAY
Consulting Paleontologist
Houston, Texas
Box 1957, Rt. 17 M. 2-1134

RALPH S. JACKSON
Consulting Geophysicist
BEEVILLE TEXAS

J. S. HUDNALL G. W. PIRTLE
HUDNALL & PIRTLE
Petroleum Geologists
Appraisals Reports
Peoples Nat'l. Bank Bldg. TYLER, TEXAS

W. P. JENNY
Consulting Geologist and Geophysicist
Specializing in MICROMAGNETIC SURVEYS, GEOLOGICAL INTERPRETATIONS and CORRELATIONS of seismic, gravimetric, electric and magnetic surveys.
1404 Esperson Bldg. HOUSTON, TEXAS

JOHN S. IVY
Geologist
1124 Niels Esperson Bldg., HOUSTON, TEXAS

TEXAS

V. ROBERT KERR
Consulting Seismologist
Original and Review Interpretations
Associated with
CUMMINS, BERGER AND PISHNY
Commercial Standard Bldg. Fort Worth 2, Tex.

LESTER A. LUCKE
Geologist
900 Brook Avenue
Wichita Falls, Texas

PHIL F. MARTYN
Petroleum Geologist
2703 Gulf Building
Charter 4-0770 Houston 2, Texas

GEORGE D. MITCHELL, JR.
Geologist and Geophysicist
ADVANCED EXPLORATION COMPANY
622 First Nat'l Bank Bldg. Houston 2, Texas

P. E. NARVARTE
Consulting Geophysicist
Seismic Interpretations
Specializing in Faulting and Velocity Analysis
Current Supervision and Review
307 Insurance Building San Antonio, Texas

DABNEY E. PETTY
10 Tenth Street
SAN ANTONIO, TEXAS
No Commercial Work Undertaken

ROBERT H. RAY
ROBERT H. RAY, INC.
Geophysical Engineering
Gravity Surveys and Interpretations
Natl. Std. Bldg. Houston 2, Texas

H. KLAUS
Geologist and Geophysicist
KLAUS EXPLORATION COMPANY
Geophysical Surveys and Interpretations
Gravitymeter, Torsion Balance
and Magnetometer
Box 1617, Lubbock, Texas

JOHN D. MARR
Geologist and Geophysicist
SEISMIC EXPLORATIONS, INC.
Gulf Building Houston, Texas

HAYDON W. McDONNOLD
Geologist and Geophysicist
KEYSTONE EXPLORATION COMPANY
2813 Westheimer Road Houston, Texas

R. B. MITCHELL
Consulting Geologist
THE R. B. MITCHELL COMPANY
City National Bank Bldg. Houston 2, Texas

LEONARD J. NEUMAN
Geology and Geophysics
Contractor and Counselor
Reflection and Refraction Surveys
943 Mellie Esperson Bldg. Houston, Texas

J. C. POLLARD
Robert H. Ray, Inc.
Rogers-Ray, Inc.
Geophysical Engineering
National Standard Bldg. Houston 2, Texas

F. F. REYNOLDS
Geophysicist
SEISMIC EXPLORATIONS, INC.
Natl. Std. Bldg. Houston 2, Texas

TEXAS

SIDNEY SCHAFER
Consulting Geophysicist
Seismic Reviews Interpretations
Exploration Problems
3775 Harper St. Houston 5, Texas

Henry F. Schweer Geo. P. Hardison
SCHWEER AND HARDISON
Independent Consulting Petroleum Geologists
426-28 Waggoner Building
Wichita Falls, Texas

A. L. SELIG
Consulting Geologist
Gulf Building Houston, Texas

E. JOE SHIMEK HART BROWN
GEOPHYSICAL ASSOCIATES
Seismic
P.O. Box 6005 Houston 6, Texas

WM. H. SPICE, JR.
Consulting Geologist
2101-02 Alamo National Building
SAN ANTONIO, TEXAS

CHARLES C. ZIMMERMAN
Geologist and Geophysicist
KEYSTONE EXPLORATION COMPANY
2813 Westheimer Road Houston, Texas

HARRY C. SPOOR, JR.
Consulting Geologist
Petroleum . . . . . Natural Gas
Commerce Building Houston, Texas

W. W. WEST
PERMIAN BASIN SAMPLE LABORATORY
106 South Loraine Phone: 1685 Midland, Texas
All current West Texas and New Mexico Permian Basin wildcat and key pool well sample descriptions on a monthly subscription basis.
Descriptions on old wells.

WEST VIRGINIA

DAVID B. REGER
Consulting Geologist
217 High Street
MORGANTOWN WEST VIRGINIA

WYOMING

E. W. KRAMPERT
Geologist
P.O. Box 1106
CASPER, WYOMING

HENRY CARTER REA
Consulting Geologist
Specialist in Photogeology
Box 294
CASPER, WYOMING

GEOLOGICAL AND GEOPHYSICAL SOCIETIES

THE SOCIETY OF EXPLORATION GEOPHYSICISTS

President - - - - - - - - - Cecil H. Green
Geophysical Service, Inc., 1311 Republic Bank Building, Dallas, Texas
Vice-President - - - - - - - L. L. Nettleton
Gravity Meter Exploration Co.
1348 Esperson Bldg., Houston, Tex.
Editor - - - - - - - - - M. King Hubbert
Shell Oil Company, Inc.
Houston, Texas
Secretary-Treasurer - - - Thomas A. Manhart
Seismograph Service Corporation
Box 1590, Tulsa, Oklahoma
Past-President - - - - - - - - J. J. Jakosky
University of Southern California
Los Angeles
Business Manager - - - - Colin C. Campbell
213 Ritz Building, Tulsa, Oklahoma
P.O. Box 1614

CALIFORNIA

PACIFIC SECTION AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

President - - - - - Martin Van Couvering
1734 Hillside Drive, Glendale, California
Vice-President - - - - William P. Winham
Box 2437 Terminal Annex, Los Angeles 54
Secretary-Treasurer - - - Clifton W. Johnson
430 Richfield Building, Los Angeles 13

Monthly Luncheons: First Thursday each month, Clark Hotel, 426 South Hill St., Los Angeles

COLORADO

ROCKY MOUNTAIN ASSOCIATION OF GEOLOGISTS
DENVER, COLORADO

President - - - - - - - - - C. A. Heiland
Heiland Research Corporation
130 East Fifth Ave.
1st Vice-President - - - - Robert McMillan
Geophoto Services, Inc.
305 E & C Building
2nd Vice-President - - - - - A. W. Cullen
1024 Continental Oil Building
Secretary-Treasurer - - - - - - N. W. Bass
U. S. Geological Survey, 300 New Customhouse

Evening dinner (6:30) and technical program (8:00) first Tuesday each month or by announcement.

FLORIDA

SOUTHEASTERN GEOLOGICAL SOCIETY
Box 841
TALLAHASSEE, FLORIDA

President - - - - - - - - - H. A. Sellin
Magnolia Petroleum Company
Vice-President - - - - - - B. B. Spaulding
The Texas Company, Box 21
Secretary-Treasurer - - - - - Lois J. Schulz
The California Company, Box 371

Meetings will be announced. Visiting geologists and friends are welcome.

ILLINOIS

ILLINOIS GEOLOGICAL SOCIETY

President - - - - - - - - - E. E. Rehn
Sohio Petroleum Company
Box 537, Mt. Vernon
Vice-President - - - - - - John B. Patton
Indiana University
Bloomington, Indiana
Secretary-Treasurer - - - - - Charles Doh
Schlumberger Well Surveying Corporation
Box 571, Mattoon

Meetings will be announced.

INDIANA-KENTUCKY

INDIANA-KENTUCKY GEOLOGICAL SOCIETY
EVANSVILLE, INDIANA

President - - - - - - - - J. Albert Brown
Sohio Petroleum Company, Damron Bldg.
Owensboro, Kentucky
Vice-President - - - - - - George E. Taylor
Continental Oil Company, 606 Division St.
Evansville, Indiana
Secretary-Treasurer - - - - - P. L. Keller
Great Lakes Carbon Company, American Bldg.
Evansville, Indiana

Meetings will be announced.

KANSAS

KANSAS GEOLOGICAL SOCIETY
WICHITA, KANSAS

President - - - - - - - - E. Gail Carpenter
Consulting, 240 N. Pinecrest
Vice-President - - - - - - Lee H. Cornell
Stanolind Oil and Gas Company
Secretary-Treasurer - - - - - Don W. Payne
Sinclair Prairie Oil Company

Regular Meetings: 7:30 P.M., Geological Room, University of Wichita, first Tuesday of each month. The Society sponsors the Kansas Well Log Bureau, 412 Union National Bank Building, and the Kansas Well Sample Bureau, 137 North Topeka.

LOUISIANA

NEW ORLEANS GEOLOGICAL SOCIETY
NEW ORLEANS, LOUISIANA

President - - - - - - - - D. D. Utterback
Houston Oil Company of Texas
1701 Pere Marquette Bldg.
Vice-President and Program Chairman - - -
- - - - - - - - - - Joe B. Hudson
Humble Oil and Refining Company
Secretary-Treasurer - - - - - D. N. Rockwood
Union Producing Company, Box 1628

Meets the first Monday of every month, October-May inclusive, 7:30 P.M., St. Charles Hotel. Special meetings by announcement. Visiting geologists cordially invited.

LOUISIANA

THE SHREVEPORT GEOLOGICAL SOCIETY
SHREVEPORT, LOUISIANA

President - - - - - - - - W. E. Wallace, Jr.
Sohio Petroleum Company, Atlas Building
Vice-President - - - - - - - Edward W. Scott
Union Oil Company of California
Ricou-Brewster Building
Secretary-Treasurer - - - - Richard T. Chapman
Stanolind Oil and Gas Company, Box 1092

Meets monthly, September to May, inclusive, in the State Exhibit Building, Fair Grounds. All meetings by announcement.

LOUISIANA

SOUTH LOUISIANA GEOLOGICAL SOCIETY
LAKE CHARLES, LOUISIANA

President - - - - - - - - Bruce M. Choate
Atlantic Refining Company
Vice-President - - - - - - - - Roy A. Payne
Gulf Oil Corporation
Secretary - - - - - - - - W. Farrin Hoover
Stanolind Oil and Gas Company, Box 54
Treasurer - - - - - - - - - W. B. Neill
Stanolind Oil and Gas Company

Meetings: Dinner and business meetings third Tuesday of each month at 7:00 P.M. at the Majestic Hotel. Special meetings by announcement. Visiting geologists are welcome.

MICHIGAN

MICHIGAN GEOLOGICAL SOCIETY

President - - - - - - - - Charles K. Clark
Pure Oil Company
402 2d Natl. Bank Bldg., Saginaw
Vice-President - - - - - - - - W. A. Kelly
Michigan State College
East Lansing
Secretary-Treasurer - - - Harry J. Hardenberg
Michigan Geological Survey
Capitol Savings and Loan Bldg., Lansing
Business Manager - - - - - Jack Mortenson
Sohio Petroleum Company, Mt. Pleasant

Meetings: Monthly, November through May, at Michigan State College, East Lansing, Michigan. Informal dinners at 6:30 P.M., followed by discussions. Visiting geologists are welcome.

MISSISSIPPI

MISSISSIPPI GEOLOGICAL SOCIETY
JACKSON, MISSISSIPPI

President - - - - - - - - - - H. L. Spyres
Skelly Oil Company
Vice-President - - - - - - - - R. D. Sprague
Sinclair Wyoming Oil Company
Secretary-Treasurer - - - - - Carl F. Grubb
Superior Oil Company
Tower Building

Meetings: First and third Thursdays of each month, from October to May, inclusive, at 7:30 P.M., Edwards Hotel, Jackson, Mississippi. Visiting geologists welcome to all meetings.

OKLAHOMA

ARDMORE GEOLOGICAL SOCIETY
ARDMORE, OKLAHOMA

President - - - - - - - - Robert W. Kline
Sinclair Prairie Oil Company, Box 978
Vice-President - - - - - - - - B. W. James
Phillips Petroleum Company, Box 958
Secretary-Treasurer - - - - - W. R. Johnson
The Texas Company Box 539

Dinner meetings will be held at 7:00 P.M. on the first Wednesday of every month from October to May, inclusive, at the Ardmore Hotel.

OKLAHOMA CITY GEOLOGICAL SOCIETY
OKLAHOMA CITY, OKLAHOMA

President - - - - - - - - Harold J. Kleen
Skelly Oil Company
Vice-President - - - - - - - - Ben F. Baldwin
Stanolind Oil and Gas Company
Secretary - - - - - - - - - L. R. Wilson
Carter Oil Company
1300 Apco Tower
Treasurer - - - - - - - - R. W. Edmund
Globe Oil and Refining Company

Meetings: Technical program each month, subject to call by Program Committee, Oklahoma City University, 24th Street and Blackwelder. Luncheons: Every second and fourth Thursday of each month, at 12:00 noon. Y.W.C.A.

SHAWNEE GEOLOGICAL SOCIETY
SHAWNEE, OKLAHOMA

President - - - - - - - - Henry A. Campo
Atlantic Refining Company, Box 169
Shawnee
Vice-President - - - - - - - Fred J. Smith
Sinclair Prairie Oil Company
Box 991, Seminole
Secretary-Treasurer - - - - Marcelle Mousley
Atlantic Refining Company, Box 169
Shawnee

Meets the fourth Thursday of each month at 8:00 P.M., at the Aldridge Hotel. Visiting geologists welcome.

TULSA GEOLOGICAL SOCIETY
TULSA, OKLAHOMA

President - - - - - - - - Charles G. Carlson
Consulting Geologist, 922 Thompson Building
1st Vice-President - - - - - - Jerry E. Upp
Amerada Petroleum Corporation, Box 2040
2nd Vice-President - - - - - L. E. Fitts, Jr.
Sinclair Prairie Oil Company, Box 521
Secretary-Treasurer - - - - - - V. L. Frost
Ohio Oil Company, Thompson Building
Editor - - - - - - - - - Robert F. Walters
Box 661, Gulf Oil Corporation

Meetings: First and third Mondays, each month, from October to May, inclusive, at 8:00 P.M., University of Tulsa, Kendall Hall Auditorium. Luncheons: Every Friday (October-May), Chamber of Commerce Building.

PENNSYLVANIA

PITTSBURGH GEOLOGICAL SOCIETY

PITTSBURGH, PENNSYLVANIA

President - - - - - - - - - S. S. Philbrick
United States Engineers, 925 New Federal Bldg.
Vice-President - - - - - - John T. Galey
Independent, Box 1675
Secretary - - - - - - - - - David K. Kirk
Gulf Research and Development Co., Box 2038
Treasurer - - - - - - - - C. H. Feldmiller
111 Haldane Avenue, Pittsburgh 5

Meetings held each month, except during the summer. All meetings and other activities by special announcement.

TEXAS

PANHANDLE GEOLOGICAL SOCIETY

AMARILLO, TEXAS

President - - - - - - - Graydon L. Meholin
Sinclair Prairie Oil Company, Box 1242
Vice-President - - - - - - Paul A. Grant
Gulf Oil Corporation, Box 110
Secretary-Treasurer - - - - - Robert J. Gutru
Cities Service Oil Company, Box 350

Meetings: Luncheon 1st and 3d Wednesdays of each month, 12:00 noon, Herring Hotel. Special night meetings by announcement.

TEXAS

CORPUS CHRISTI GEOLOGICAL SOCIETY

CORPUS CHRISTI, TEXAS

President - - - - - - - - - Dale L. Benson
Sinclair Prairie Oil Company, Box 480
Vice-President - - - Robert D. Hendrickson
Tide Water Associated Oil Company
Secretary-Treasurer - - - - - H. C. Cooke
c/o O. G. McClain, 224 Nixon Building

Regular luncheons, every Wednesday, Petroleum Room, Plaza Hotel, 12:05 Special night meetings by announcement.

DALLAS GEOLOGICAL SOCIETY

DALLAS, TEXAS

President - - - - - - - - - Willis G. Meyer
Meyer and Achtschin
502 Continental Building
Vice-President - - - - - - John M. Clayton
Seaboard Oil Company
1400 Continental Building
Secretary-Treasurer - - - - - W. W. Newton
Geotechnical Corporation, Box 7166

Meetings: Monthly luncheons by announcement. Special night meetings by announcement.

EAST TEXAS GEOLOGICAL SOCIETY

TYLER, TEXAS

President - - - - - - - - - T. H. Shelby, Jr.
Humble Oil and Refining Company
Vice-President - - - - - - - - - L. F. Lees
Phillips Petroleum Company
Box 208
Secretary-Treasurer - - - - Walter E. Long
Magnolia Petroleum Company
Box 780

Luncheons: Each week, Monday noon, Blackstone Hotel.

Evening meetings and programs will be announced. Visiting geologists and friends are welcome.

FORT WORTH GEOLOGICAL SOCIETY

FORT WORTH, TEXAS

President - - - - - - - - - C. D. Cordry
Gulf Oil Corporation
Box 1290
Vice-President - - - - - - - R. H. Schweers
The Texas Company, Box 1720
Secretary-Treasurer - - - - - R. W. Dudley
Pure Oil Company
Box 2107

Meetings: Luncheon at noon, Hotel Texas, first and third Mondays of each month. Visiting geologists and friends are invited and welcome at all meetings.

HOUSTON GEOLOGICAL SOCIETY

HOUSTON, TEXAS

President - - - - - - - - Charles H. Sample
J. M. Huber Corporation
721 Bankers Mortgage Bldg.
Vice-President - - - - - - - - A. F. Childers
Gulf Oil Corporation, Box 2100
Secretary - - - - - - Hershal C. Ferguson
Consultant, 1208 Esperson Building
Treasurer - - - - - - - - - Eugene L. Earl
Crown Central Petroleum Corporation

Regular meeting held the second and fourth Mondays at noon (12 o'clock), Mezzanine floor, Rice Hotel. For any particulars pertaining to the meetings write or call the secretary.

NORTH TEXAS GEOLOGICAL SOCIETY

WICHITA FALLS, TEXAS

President - - - - - - - - Dolphe E. Simic
Bay Petroleum Corporation
Vice-President - - - - - - - Lynn L. Harden
Sinclair Prairie Oil Company
Secretary-Treasurer - - - - - D. T. Richards
Consulting, 1709 Buchanan Street

Meetings: Each week, Tuesday, 12:30 P.M., Texas Electric Auditorium; Each month, first Thursday evening. Special night meetings announced. All geologists always welcome.

TEXAS

SOUTH TEXAS SECTION AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

SAN ANTONIO, TEXAS

President - - - - - - - - - Guy E. Green
Santa Clara Oil Company
1016 South Texas Building

Vice-President - - - - - - Van A. Petty, Jr.
Petty Geophysical Company

Secretary-Treasurer - - - - - - - J. Boyd Best
The Ohio Oil Company
1417 Milam Building

Meetings: One regular meeting each month in San Antonio. Luncheon every Monday noon at Milam Cafeteria, San Antonio.

WEST TEXAS GEOLOGICAL SOCIETY

MIDLAND, TEXAS

President - - - - - - - W. J. Hilseweck
Gulf Oil Corporation, Box 1150

Vice-President - - - - - W. A. Waldschmidt
Argo Oil Corporation, Box 1814

Secretary-Treasurer - - - Charles F. Henderson
Stanolind Oil and Gas Company, Box 1540

Meetings will be announced.

WEST VIRGINIA

THE APPALACHIAN GEOLOGICAL SOCIETY

CHARLESTON, WEST VIRGINIA
P. O. Box 2605

President - - - - - - - - Veleair C. Smith
1901 Kanawha Valley Building

Vice-President - - - - - - W. B. Maxwell
United Fuel Gas Company, Box 1273

Secretary-Treasurer - - - - - - R. L. Alkire
605 Union Building

Editor - - - - - - - - - - J. D. Castner
Box 1433

Meetings: Second Monday, each month, except June, July, and August, at 6:30 P.M., Kanawha Hotel.

WYOMING

WYOMING GEOLOGICAL ASSOCIATION

CASPER, WYOMING
P. O. Box 545

President - - - - - - - Rolland W. McCanne
The Ohio Oil Company

1st Vice-President - - - - Waynard G. Olson
Continental Oil Company

2d Vice-President (Programs) Thomas C. Hiestand
Cities Service Oil Company

Secretary-Treasurer - - - - - George Steele
Northern Utilities Company

Informal luncheon meetings every Friday, 12 noon, Townsend Hotel. Visiting geologists welcome. Special meetings by announcement.

DIRECTORY OF GEOLOGICAL MATERIAL IN NORTH AMERICA

J. V. HOWELL AND A. I. LEVORSEN

I. General Material:—National and continental in area
  A. Publications and non-commercial publishing agencies, regional, national, and continental
  B. Bibliographies, general
  C. Dictionaries, glossaries, encyclopedias, statistics, handbooks
  D. Miscellaneous books and publications of general geological interest
  E. Commercial map publishers
  F. Regional and national geologic and physiographic maps
  G. State and Province geological maps
  H. Trade journals: oil, gas, mineral industry
  I. Libraries furnishing photostat and microfilm service
  J. Thin-section and rock-polishing service
II. Specific material:—State and Province in area
  A. Canada, by provinces and Newfoundland
  B. Central American countries
  C. Mexico
  D. United States—states and territories

112 Pp. *Originally published as Part II of the August, 1946, Bulletin.* 75¢

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
BOX 979, TULSA 1, OKLAHOMA, U.S.A.

Western
SERVES
COAST TO COAST
BORDER TO BORDER
This map indicates the number and type of Western crews which have operated in each state from January to June, 1947.
KEY
Seismic Survey Parties
Gravity Meter Survey Parties
Core Drill & Electric Logging Parties
Elevation Meter Survey Parties
Main Office and Plant
Division Headquarters

Western's activities since the inception of the company in 1933 include operations in every major producing and potential petroleum producing province in the United States. This wide experience, solving all types of geophysical problems, together with superior personnel, equipment and research facilities enables *Western* to meet every requirement of operators desiring the most complete and highly advanced geophysical service.

The accuracy of its surveys is attested by its numerous clients and by the many discovery wells which have been located on the basis of Western surveys.

In addition to the domestic operations depicted, Western field parties and/or instruments are now operating in Paraguay, Argentine, Italy, France and China. *Western services are available in any part of the world.*

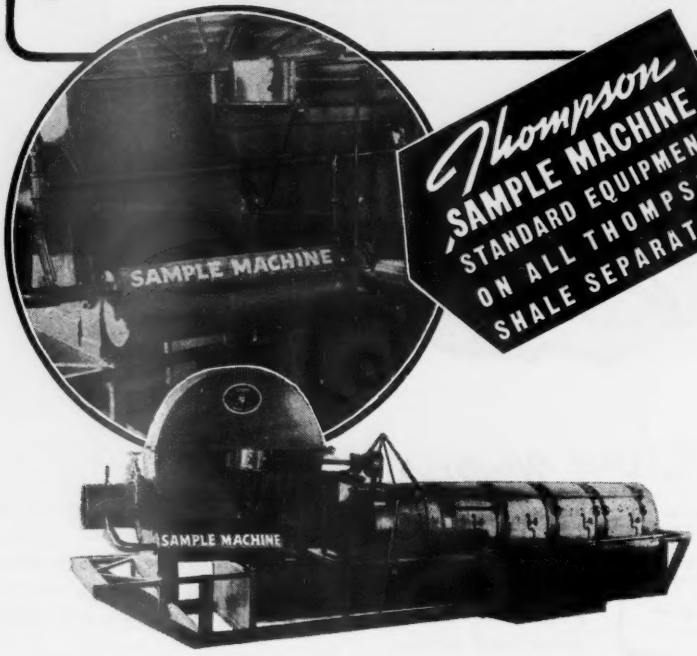
WESTERN MANUFACTURES FOR SALE OR *RENTAL*—
Seismic Instruments and Equipment • Gravity Meters • Elevation Meters • Electrical Logging Units • Portable Shot Hole and Core Drilling Rigs

Western GEOPHYSICAL COMPANY

HENRY SALVATORI PRESIDENT

EDISON BUILDING, LOS ANGELES 13, CALIFORNIA, U.S.A.

The Easiest . . . Quickest . . . and most Economical Way to get DEPENDABLE SAMPLES



In addition to doing a thorough job of reconditioning drilling mud, the Thompson Shale Separator provides geologists with accurate foot by foot samples of cuttings and mud. By pushing a lever, part of the flow of mud is diverted into the Sample Machine. Here the mud is separated into . . . shale and abrasives . . . drilling mud . . . and deposited into two, easily accessible, catch basins. Many operators claim this alone is worth the entire cost of the Thompson Separator. Look for the Sample Machine on the Thompson Separator . . . it's the field-tested method of obtaining dependable samples.

THOMPSON TOOL CO.

IOWA PARK, TEXAS

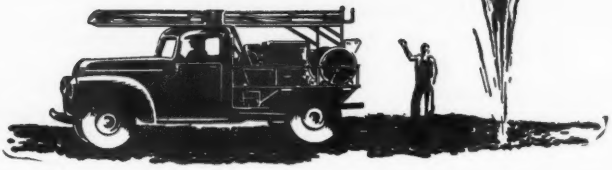
KEEPS DRILLING MUD CLEAN — PROVIDES *TRUE* SAMPLES OF CUTTINGS

General
GEOPHYSICAL COMPANY HOUSTON

ACCURATE
GEOPHYSICAL
SURVEYS

•

CORE DRILLING



TRIANGLE BLUE PRINT & SUPPLY COMPANY

We Repair

ALL BRANDS OF MICROSCOPES AND SURVEYING INSTRUMENTS
LET US GIVE YOU AN ESTIMATE ON YOUR WORK

12 West Fourth Street, Tulsa, Oklahoma

TECTONIC MAP OF SOUTHERN CALIFORNIA

BY R. D. REED AND J. S. HOLLISTER

In 10 colors. From "Structural Evolution of Southern California," *BULL. A.A.P.G.* (Dec., 1936). Scale, ½ inch = 1 mile. Map and 4 structure sections on strong ledger paper, 27 x 31 inches, rolled in tube, postpaid, $0.50.

The American Association of Petroleum Geologists, Box 979, Tulsa 1, Oklahoma

MINERAL RESOURCES OF CHINA

By V. C. Juan

June-July, 1946 Issue, Part II, Economic Geology

75 cents per copy In lots of 10—$6.00

The Economic Geology Publishing Company
100 Natural Resources Building, Urbana, Illinois

GEOPHYSICAL SURVEYS

UNIVERSAL EXPLORATION COMPANY

2044 Richmond Road

HOUSTON 6, TEXAS

Paul Charrin, Pres. — John Gilmore, V.P. — C. C. Hinson, V.P.

EARLY GEOPHYSICAL PAPERS

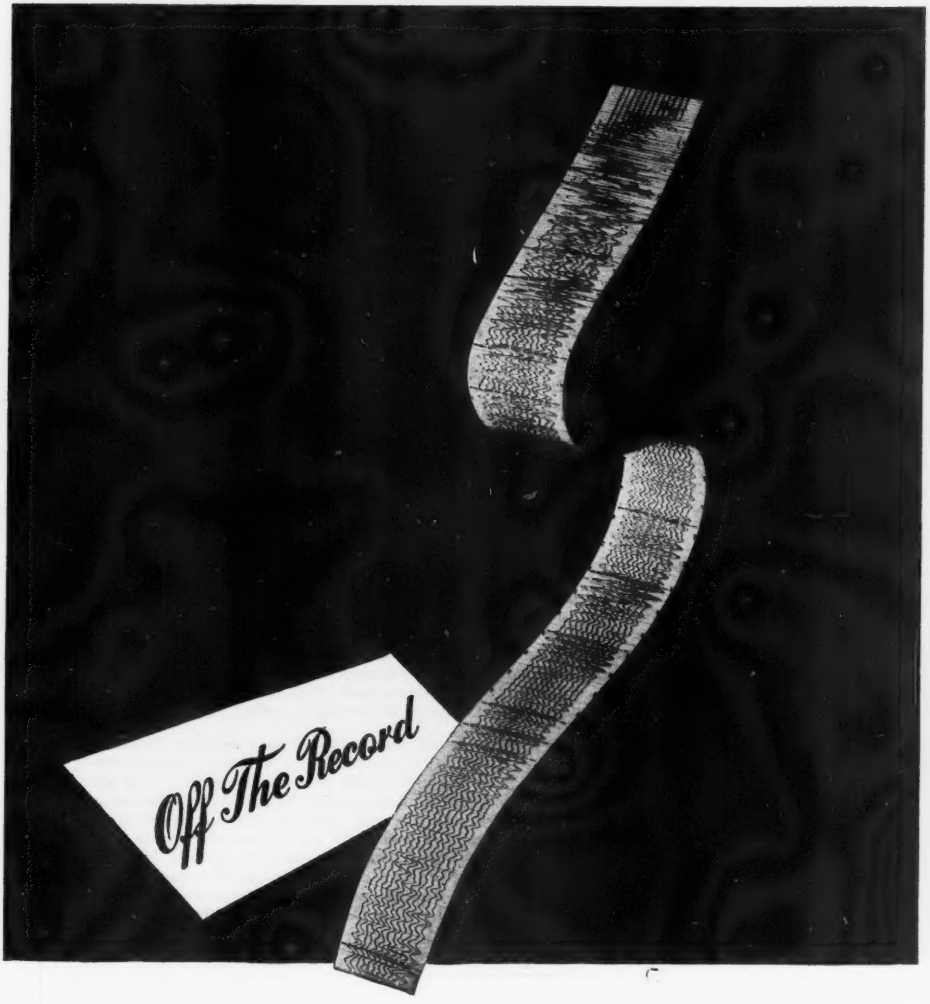
of the Society of Exploration Geophysicists

One volume containing 57 papers by men who were outstanding in the early development of geophysical methods of exploration, published in other journals prior to the first volume of GEOPHYSICS.

$5.00 to S.E.G. Members and Subscribers.
$6.00 to all others. Postpaid.

Address orders to

SOCIETY OF EXPLORATION GEOPHYSICISTS
P.O. Box 1614 Tulsa, Oklahoma



Off the record can come misinterpretations that *may* lead to costly and unsuccessful leasing and drilling, or, perhaps, the condemnation of productive acreage.

That the Seismic staff of seismologists, now entering its fifteenth year as an organization, is capable of successfully directing an exploration campaign of any magnitude is clearly reflected in its record of operations . . . a record highlighted by *accurate interpretations*.

SEISMIC

SEISMIC EXPLORATIONS, INC.

Gulf Bldg. Houston, Texas

Established 1932

MIOCENE STRATIGRAPHY OF CALIFORNIA

By ROBERT M. KLEINPELL

This Work Establishes a Standard Chronologic-Biostratigraphic Section for the Miocene of California and Compares It with the Typical Stratigraphic Sequence of the Tertiary of Europe

---

WHAT OTHERS HAVE WRITTEN ABOUT IT

"In spite of any defects it may have, moreover, many of us suspect that Kleinpell's book is of the kind called epoch-making. If so, in 50 or 100 years it will stand out like a beacon among its contemporaries and, along with a very few others of them will read with a 'modern' tang. Oppel's 'Die Juraformation,' or Suess' 'Die Entstehung der Alpen,' or to go back to the beginning, De Saussure's 'Les Voyages dans les Alpes' may be cited among older geological classics that are now distinguished by this same tang."—Ralph D. Reed in *Journal of Paleontology*, Vol. 13, No. 6 (November, 1939), p. 625.

"The Neogene of California is disposed in tectonic basins, about a dozen in number, from Humboldt in the north to Los Angeles in the south. About half-way along is the Paso Robles basin, and in this lies the Reliz Canyon, which provides the author with his type section. The aerial photograph serving as frontispiece shows the area to be sufficiently arid to give a practically continuous exposure; but one must admire the painstaking determination with which so many successive associations of Foraminifera were collected, identified and tabulated. Such labour would scarcely have been thought of without the stimulus which the search for oil has given to the detailed study of Foraminifera.

"This should be the standard work on the Miocene of California for years to come."

A.M.D. in *Nature*, Vol. 144 (London, December 23, 1939), p. 1030.

- **450 pages.**
- **14 line drawings, including correlation chart in pocket.**
- **22 full-tone plates of Foraminifera.**
- **18 tables (check lists and range chart of 15 pages).**
- **Bound in blue cloth; gold stamped; paper jacket; 6x9 inches.**

PRICE: $5.00, POSTPAID

($4.50 TO A.A.P.G. MEMBERS AND ASSOCIATE MEMBERS)

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
BOX 979, TULSA 1, OKLAHOMA, U.S.A.

KEYSTONE

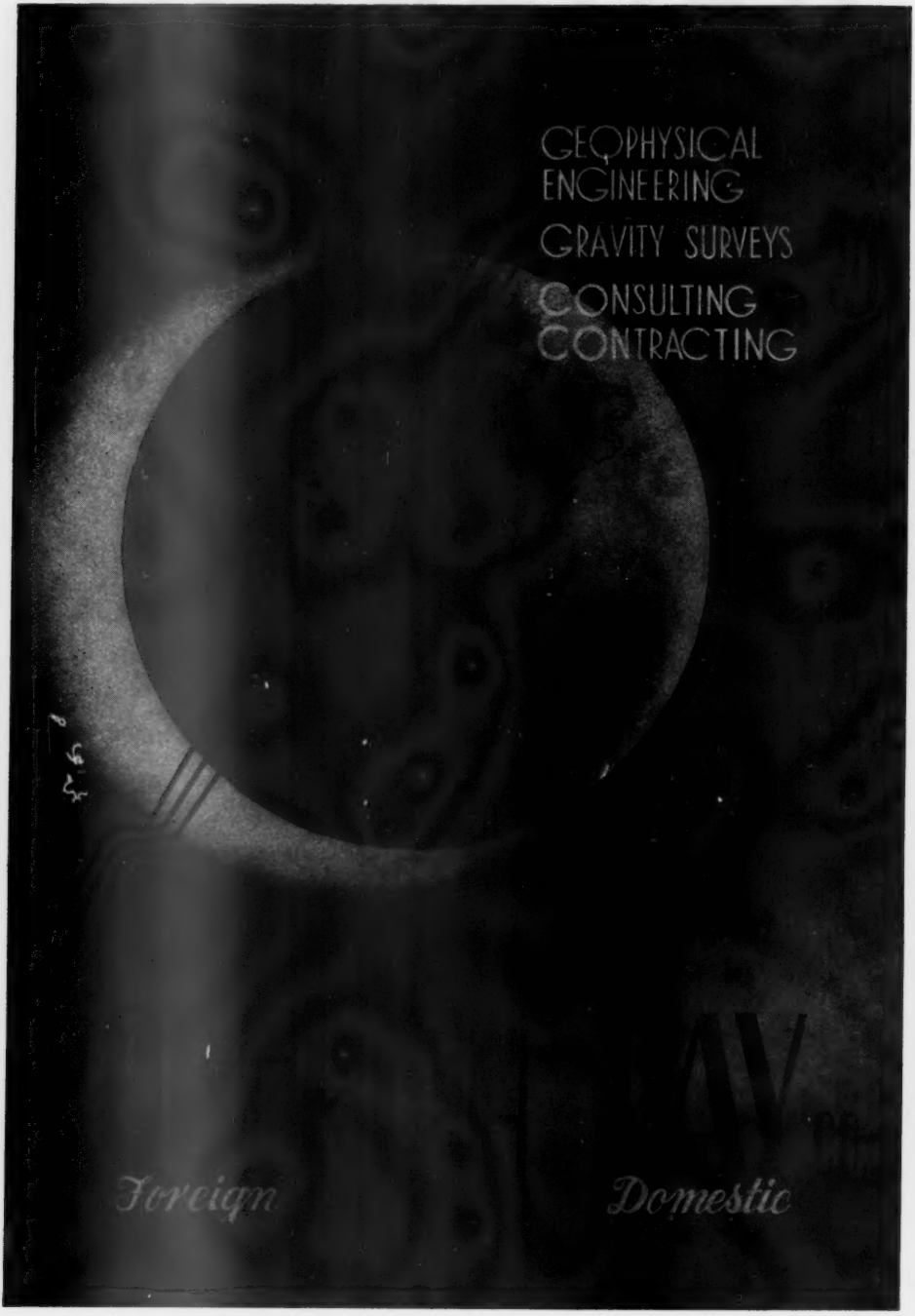
SEISMIC SURVEYS

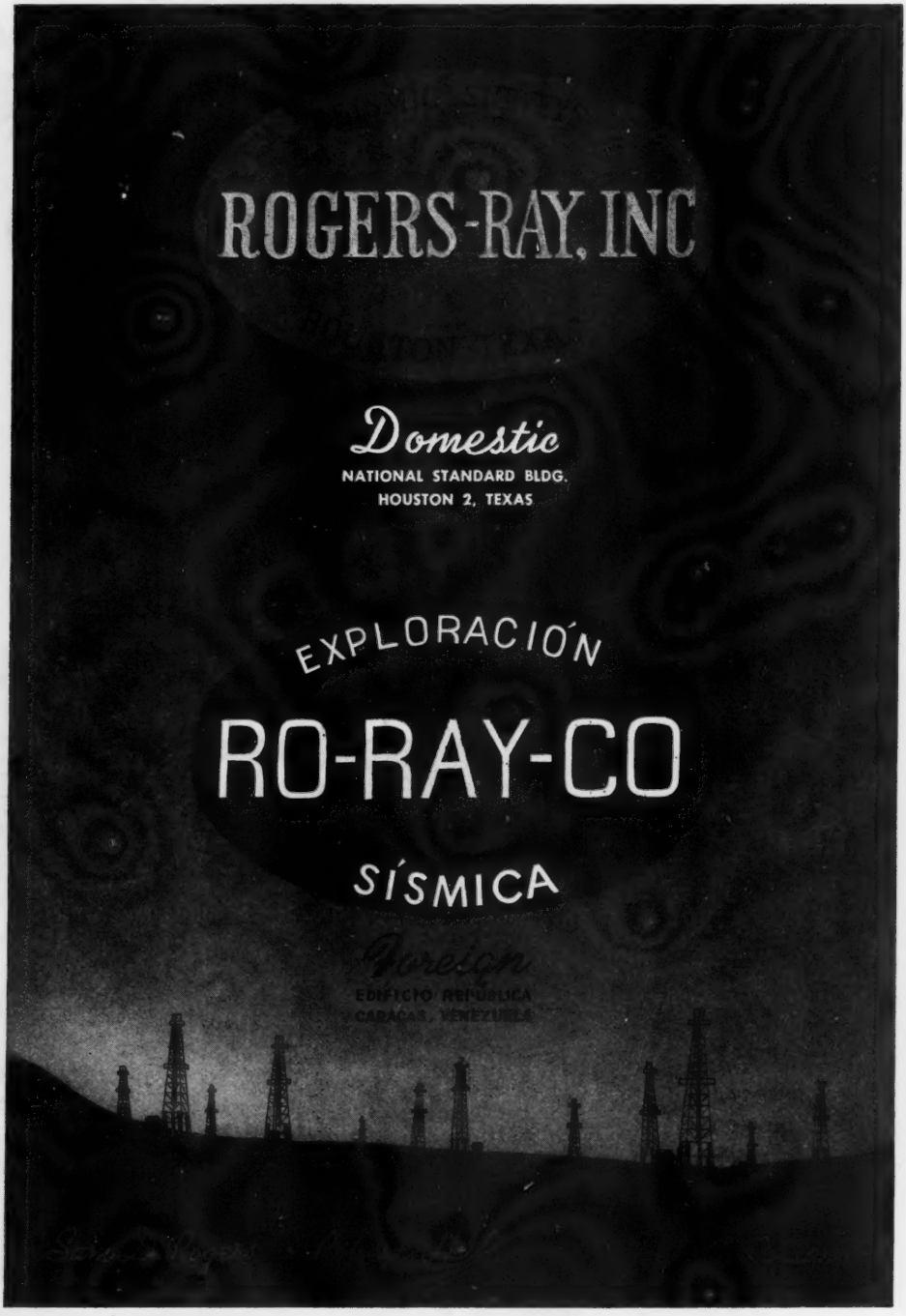
KEYSTONE EXPLORATION COMPANY

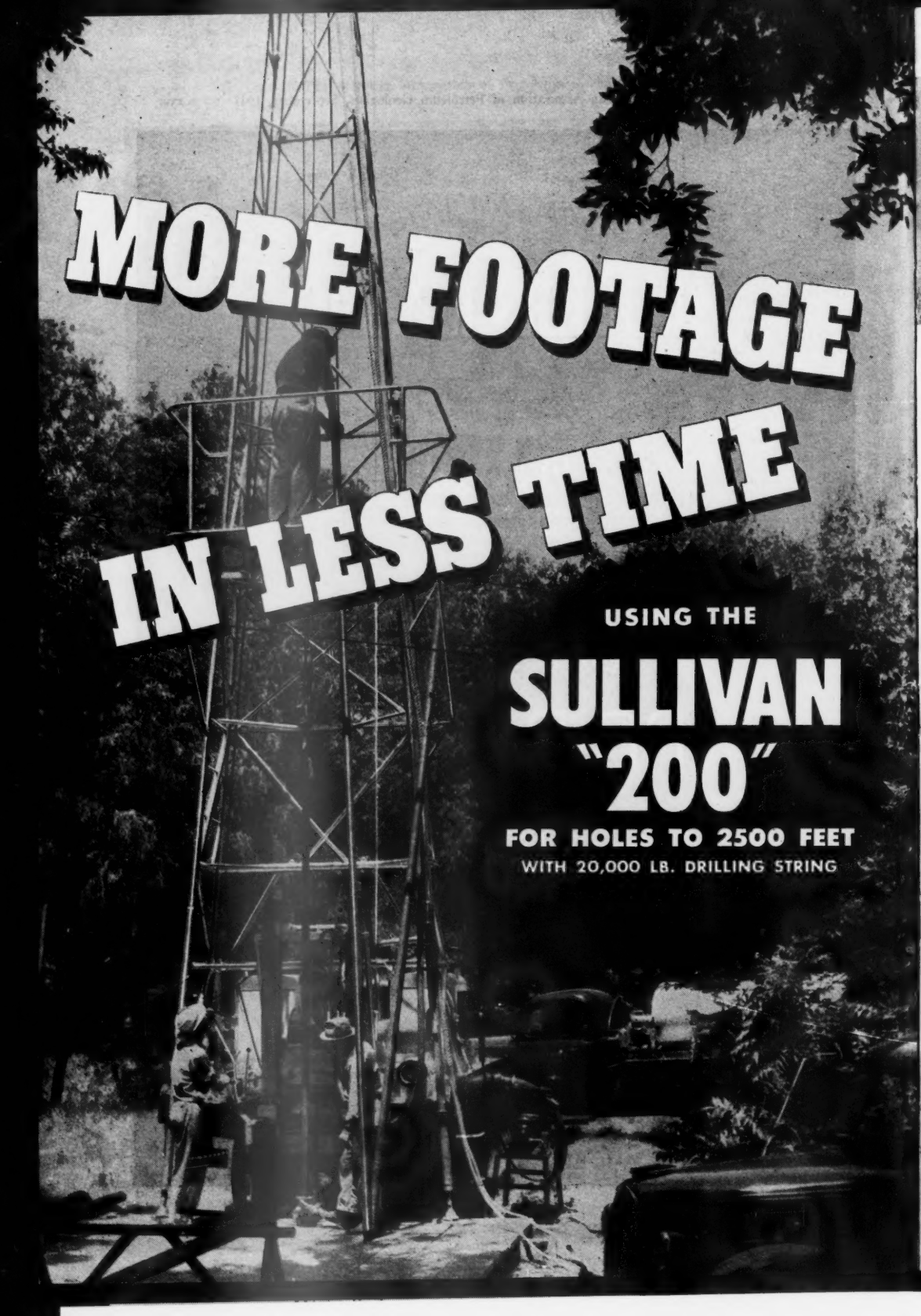
OFFICES AND LABORATORY

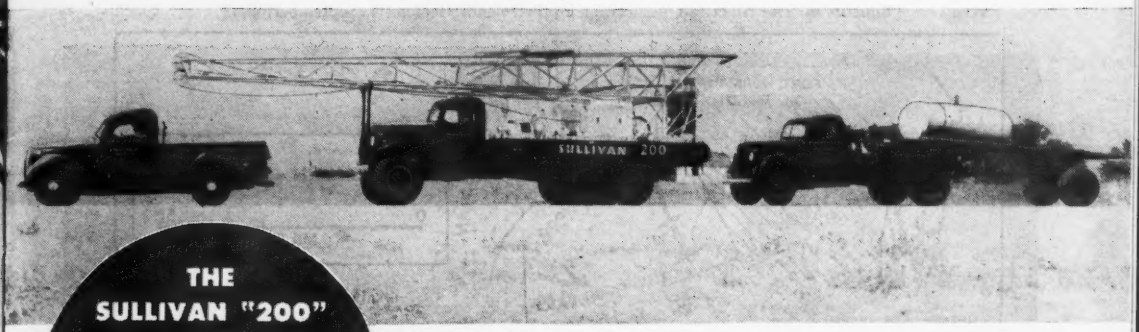
2813 WESTHEIMER ROAD

HOUSTON • TEXAS


GEOPHYSICAL
ENGINEERING
GRAVITY SURVEYS
CONSULTING
CONTRACTING
AV
Foreign
Domestic


ROGERS-RAY, INC
Domestic
NATIONAL STANDARD BLDG.
HOUSTON 2, TEXAS
EXPLORACIÓN
RO-RAY-CO
SÍSMICA
Foreign
EDIFICIO REPUBLICA
CARACAS, VENEZUELA


MORE FOOTAGE
IN LESS TIME
USING THE
SULLIVAN
"200"
FOR HOLES TO 2500 FEET
WITH 20,000 LB. DRILLING STRING



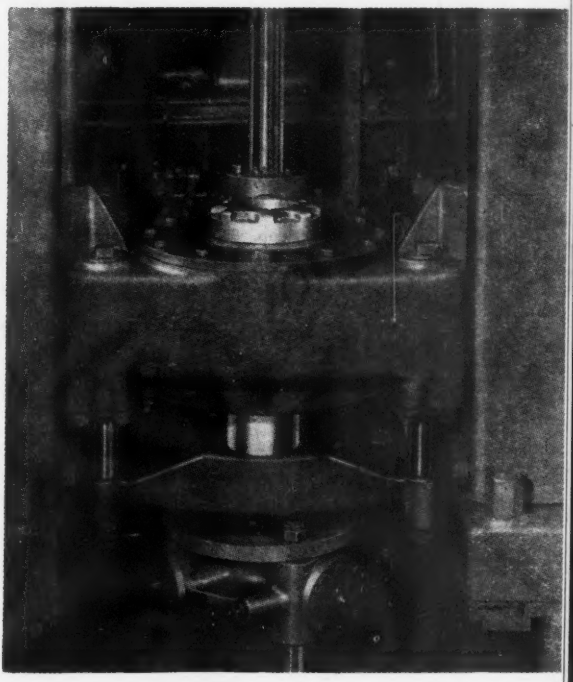
THE SULLIVAN "200" IS *Completely Portable*

A completely portable rig for exploratory drilling . . . that's the remarkable Sullivan "200"—the outstanding rig for high speed drilling at low cost. The entire rig, including the folding two-piece derrick, can be mounted on a truck, trailer, tractor or skids.

Featuring

AUTOMATIC *Hydraulic Chuck*

The Sullivan-developed Automatic Chuck is a key factor in the unsurpassed performance record of the "200" portable drill rig. It serves the triple purpose of rotary table, safety clamp and chuck when drilling without kelly. Besides saving labor, it increases drilling speed, lowers drilling costs and makes a definite contribution to greater safety. Once you see the Sullivan Automatic Chuck in action, you'll wonder how you were ever satisfied with former drilling performance! Write for descriptive bulletin.



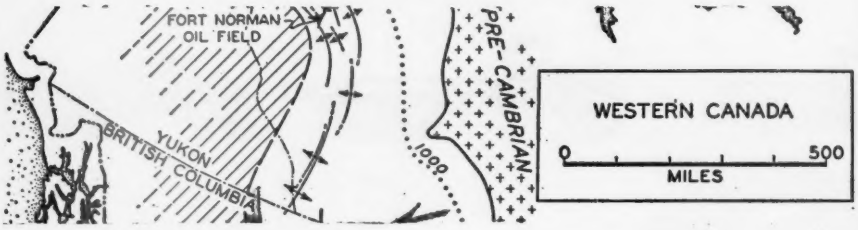
Consult a Joy Engineer

SULLIVAN DIVISION

JOY MANUFACTURING CO.

GENERAL OFFICES: HENRY W. OLIVER BUILDING
PITTSBURGH, PA.

W&D 05



1947 Printing in Paper Covers. Handy to Take with You

POSSIBLE FUTURE OIL PROVINCES OF THE UNITED STATES AND CANADA

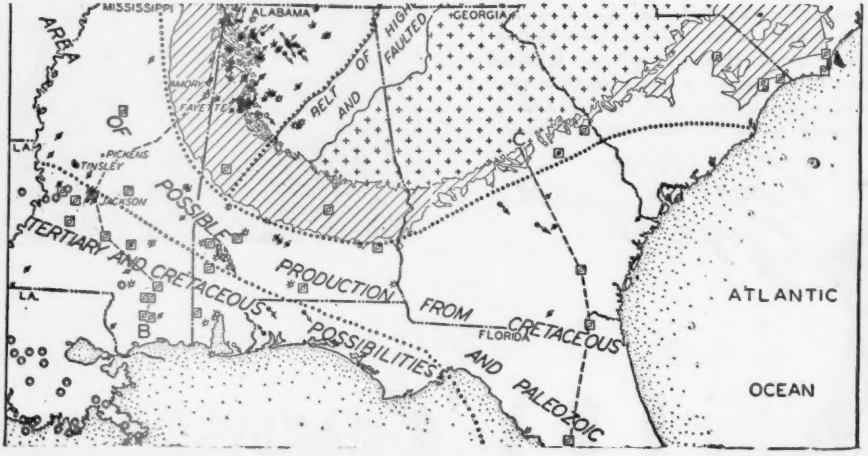
CONTENTS

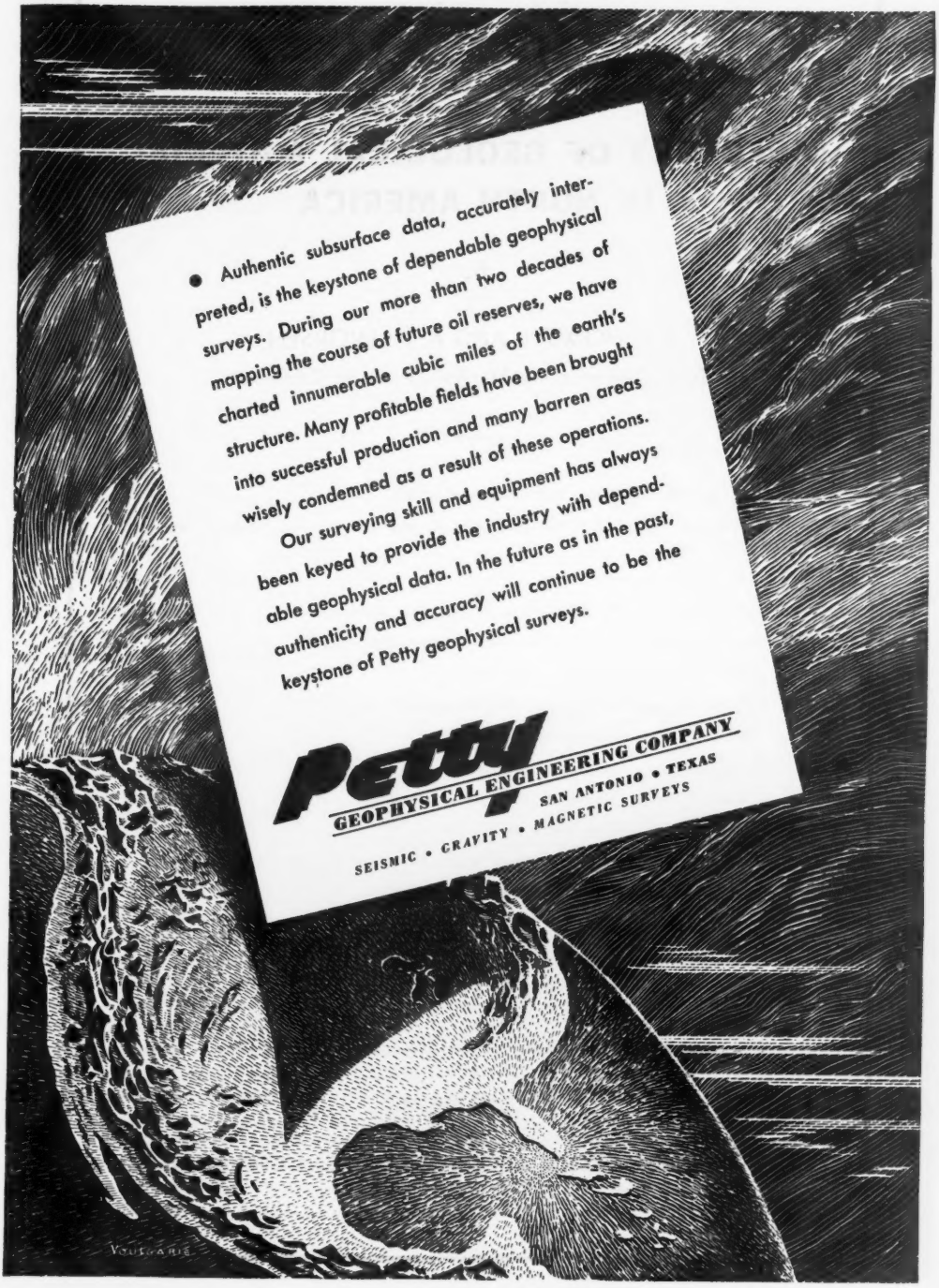
Foreword	By A. I. Levorsen
Alaska	By Philip S. Smith
Western Canada	By Alberta Society of Petroleum Geologists
Pacific Coast States	By Pacific Section, American Association of Petroleum Geologists
Rocky Mountain Region	By Rocky Mountain Association of Petroleum Geologists
Northern Mid-Continent States	By Tulsa Geological Society
West Texas	By West Texas Geological Society
Eastern Canada	By Geological Survey of Canada, Quebec Bureau of Mines, and Newfoundland Geological Survey
Eastern United States	By Appalachian Geological Society
Southeastern United States	By Mississippi Geological Society

154 pp., 83 figs. Paper cover. 6 x 9 inches
Third printing. Reproduced by photo offset process from original printing of 1941

PRICE, $1.50, POSTPAID ($1.00 TO MEMBERS AND ASSOCIATES)

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
BOX 979, TULSA 1, OKLAHOMA, U.S.A.




• Authentic subsurface data, accurately interpreted, is the keystone of dependable geophysical surveys. During our more than two decades of mapping the course of future oil reserves, we have charted innumerable cubic miles of the earth's structure. Many profitable fields have been brought into successful production and many barren areas wisely condemned as a result of these operations.
Our surveying skill and equipment has always been keyed to provide the industry with dependable geophysical data. In the future as in the past, authenticity and accuracy will continue to be the keystone of Petty geophysical surveys.
Petty
GEOPHYSICAL ENGINEERING COMPANY
SAN ANTONIO • TEXAS
SEISMIC • GRAVITY • MAGNETIC SURVEYS

Do You Have One Handy?

DIRECTORY OF GEOLOGICAL MATERIAL IN NORTH AMERICA

By

J. V. HOWELL AND A. I. LEVORSEN

Tulsa, Oklahoma, and Stanford University, California

I. General Material:—National and continental in area

A. Publications and non-commercial publishing agencies, regional, national, and continental

B. Bibliographies, general

C. Dictionaries, glossaries, encyclopedias, statistics, handbooks

D. Miscellaneous books and publications of general geological

E. Commercial map publihers

F. Regional and national geologic and physiographic maps

G. State and Province geological maps

H. Trade journals: oil, gas, mineral industry

I. Libraries furnishing photostat and microfilm service

J. Thin-section and rock-polishing service

II. Specific material:—State and Province in area

A. Canada, by provinces and Newfoundland

B. Central American countries

C. Mexico

D. United States—states and territories

Originally published as Part II of the August, 1946, Bulletin

PRICE, 75¢ POSTPAID

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

BOX 979, TULSA 1, OKLAHOMA, U.S.A.

Second Printing, 1947 *Now Ready*

STRUCTURE
OF
TYPICAL AMERICAN OIL FIELDS

A SYMPOSIUM ON THE RELATION OF OIL ACCUMULATION TO STRUCTURE

In Two Volumes By Many Authors

Originally published in 1929, the supply was soon exhausted and the continued demand has justified the current reprinting of this generally accepted description of oil fields.

CONDENSED CONTENTS BY STATES AND FIELDS

Vol. I—510 pp., 190 illus. Cloth. 6 x 9 inches. $3.00

ARKANSAS: Irma. CALIFORNIA: McKittrick. INDIANA: Tri-County. KANSAS: Fairport, Coffeyville, Rainbow Bend, Nemaha Mountains. KENTUCKY: Eastern Coal Field. LOUISIANA: Urania. MICHIGAN: Saginaw. NEW MEXICO: Artesia, OHIO: Eastern. OKLAHOMA: Morrison, Mervine, Ponca, Blackwell, South Blackwell, Garber, Crinerville, Turkey Mountain, Burbank, Glenn. TENNESSEE: Tinsleys Bottom, Celina, Spurrier-Riverton, Sumner County, Spring Creek, Glenmary, Bone Camp. TEXAS: Luling, Westbrook, Wilbarger County, Mexia and Tehuacana Fault Zones, Laredo, Archer County. WEST VIRGINIA: Copley, Cabin Creek. INDEX.

Vol. II—750 pp., 235 illus. Cloth. 6 x 9 inches. $4.00

ARKANSAS: Stephens. CALIFORNIA: Santa Maria, Ventura Avenue, Elk Hills, Long Beach. COLORADO: Florence, Northwestern. ILLINOIS: Centralia, Sandoval, Martinsville. KANSAS: Virgil, Madison, El Dorado. LOUISIANA: Caddo, Homer, Bellevue. MONTANA: Kevin-Sunburst. NEW YORK: Cattaraugus, Allegany, and Steuben Counties. OKLAHOMA: Hewitt, Cromwell, Seminole, Delaware Extension, Depew, Cushing. PENNSYLVANIA: Bradford, Scenery Hill. TEXAS: West Columbia, Stephens County, Yates, Big Lake, Petrolia, Smith-Ellis. WEST VIRGINIA: Griffithsville, Tanner Creek, Granny Creek, Grass Creek, Lost Soldier. SUMMARY: Rôle of Structure in Oil Accumulation. INDEX.

PRICE, TWO VOLUMES, $7.00, POSTPAID

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
Box 979, TULSA 1, OKLAHOMA, U.S.A.

Seismograph Equipment

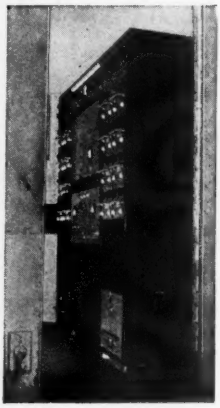
Manufactured by

NORTH AMERICAN

This equipment as well as the Portable Gravity Meter, other geophysical apparatus and precision equipment is manufactured in our own Laboratories.

REFLECTION SEISMOGRAPH UNITS

This complete 16 channel, dual recording unit is mounted in a special stainless steel body, having two power driven cable reels, completely wired, tested and ready for field service. Amplifiers have full, automatic amplitude control and complete rejection of 60 cycle power line interference. It has inverse feed back filters, 6 filter settings controlled by selector switch on instrument panel, which makes it possible to obtain any 6 filter curves. Interchangeable plug-in type filter units make it possible to readily change complete system of filter curves. Dual output is available, providing for mixed and unmixed recording simultaneously. Light weight seismometers are furnished with either fluid or electro-magnetic damping.



PORTABLE CABLE REEL

This light-weight reel, designed for use in areas inaccessible by truck, carries 1200 feet of cable and is worn on the back or chest. When laying cable it is worn on the back, the cable unreeling as the operator walks along. When reeling in, it is worn on the chest, and the cable wound on the drum by the crank as the operator walks along. Wide web belting assures comfortable fit. The complete reel weighs only 5 pounds. Weight with 1200 feet of tapered seismograph cable is only 23 pounds. The reel is available with or without cable.

NORTH AMERICAN GEOPHYSICAL COMPANY

Manufacturers of Geophysical Apparatus and Precision Equipment

2627 Westheimer Rd. Keystone 3-7408

Houston 6, Texas

TRAINING *Plus* + EXPERIENCE *Equals* =

ACCURATE INTERPRETATION IN OIL FIELD EXPLORATION

In oil exploratory work, two of the key figures in effecting accurate interpretations are the Supervisor and the Party Chief.

Republic is justly proud of the scientific training and practical experience of its Supervisors and Party Chiefs —the men who are directly responsible for the high degree of accuracy of Republic crews. These important Republic experts have an average of more than fourteen years each in the practical and technical side of oil exploration.

Your oil exploratory needs are in efficient hands when they're in the hands of REPUBLIC.

Rx

REPUBLIC EXPLORATION COMPANY

TULSA, OKLAHOMA

THE GEOTECHNICAL CORPORATION

Roland F. Beers
President

P.O. Box 7166

D4-3947 **Dallas, Texas**

GEOLOGY OF THE BARCO CONCESSION
REPUBLIC OF COLOMBIA, SOUTH AMERICA

BY
FRANK B. NOTESTEIN, CARL W. HUBMAN AND JAMES W. BOWLER
(PUBLISHED WITH THE PERMISSION OF THE COLOMBIAN PETROLEUM COMPANY)

- This is a separate ("reprint") from The Bulletin of the Geological Society of America, October, 1944
- 51 pages, 4 full-tone plates
- 10 columnar sections and stratigrahpic correlation charts, 1 structural contour map, 1 water analysis chart
- Geological map and 2 cross sections in colors (folded insert, approx. 15 x 30 inches)

PRICE, 50 CENTS, POSTPAID

Order from
THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
BOX 979, TULSA 1, OKLAHOMA, U.S.A.

C. H. FROST GRAVIMETRIC SURVEYS, INC.

C. H. FROST, *President* JOSEPH A. SHARPE, *Vice-President*

GRAVIMETERS manufactured under license from Standard Oil Development Company

GRAVIMETRIC AND MAGNETIC SURVEYS carefully conducted by competent personnel

GEOLOGIC INTERPRETATION of the results of gravimetric and magnetic surveys

4408-4410 South Peoria Avenue **Tulsa 3, Oklahoma**

SYMPOSIUM ON PENNSYLVANIAN PROBLEMS

A supplement to the May, 1947 issue of

THE JOURNAL OF GEOLOGY

The *May* issue of the *Journal* has been augmented by a supplement of more than 100 pages, containing papers presented at the 1946 meeting of the American Association for the Advancement of Science. These papers constitute a symposium on the Pennsylvanian, and have been assembled for publication, in the hope that they will be thus more useful to geologists working with Pennsylvanian problems. This supplement will be mailed without charge to all subscribers of the *Journal*.

The table of contents is as follows:

Harold R. Wanless, *Symposium on Pennsylvanian Problems*

Harold R. Wanless, *Introduction to Symposium on Pennsylvanian Problems*

Frederick B. Plummer, *Summary of Classification of the Pennsylvanian Formations of Texas, with Special Reference to the Lower Pennsylvanian of the Llano Region*

M. G. Cheney, *Pennsylvanian Classification and Correlation Problems in North-Central Texas*

Charles B. Read and Gordon H. Wood, *Distribution and Correlation of Pennsylvanian Rocks in Late Paleozoic Sedimentary Basins of Northern New Mexico*

Harold R. Wanless, *Regional Variations in Pennsylvanian Lithology*

J. Marvin Weller, *Invertebrates in Pennsylvanian Correlations*

Chalmer L. Cooper, *Role of Microfossils in Interregional Pennsylvanian Correlations*

Charles B. Read, *Pennsylvanian Floral Zones and Floral Provinces*

R. M. Kosanke, *Plant Microfossils in Correlation of Coal Beds*

Aureal T. Cross, *Spore Floras of the Pennsylvanian of West Virginia and Kentucky*

$1.25

The Journal of Geology is published in January, March, May, July, September, and November. Subscription $6.00 per year. Single copy $1.25

THE UNIVERSITY OF CHICAGO PRESS

SOUTHERN

PRECISION SEISMIC SURVEYS

REFLECTION

REFRACTION

•

DATA REANALYSIS

•

SOUTHERN GEOPHYSICAL COMPANY

SIDON HARRIS, PRESIDENT

SINCLAIR BUILDING FORT WORTH, TEXAS

GMX
DEPENDABLE GRAVITY SURVEYS
FOR MORE than twenty years we have been making and interpreting gravity surveys in most of the petroleum provinces of the world . . . localizing structural areas.
W. G. SAVILLE · A. C. PAGAN · L. L. NETTLETON
GRAVITY METER EXPLORATION CO.
geophysicists
Esperson Building, Houston, Texas

30,000 lineal miles of
BASE-FORMATION Magnetic Profile

...since March 8, 1947, for Gulf Oil Company in South America. And the first large-scale magnetic survey in history still continues. It is giving the Gulf Airborne Magnetometer and Fairchild Control procedures a real test.

A NEW OIL-EXPLORATION TOOL has opened a whole new field of possibilities for oil geologists. The Fairchild Magnetic Map is sensibly free from the surface influences that complicate ground-magnetic-survey interpretation. The Fairchild Magnetic Map shows *base formation* profiles because the Gulf Airborne Magnetometer, carried high above misleading surface influences, produces *base-formation* readings.

THE FAIRCHILD CONTROL SYSTEM means exact correlation between airborne magnetometer readings and the ground. A magnetic profile is useless without these systematized flying procedures and the control data that give it meaning. ***Write for detailed information.***

Here's the Fairchild Magnetic Survey Expedition in South America. The small truck-trailer units make up the Shoran fleet, an important link in the ground-air coordination system. The Douglas A-20 is a fast, long-range airplane, well suited for this work.

Fairchild **AERIAL SURVEYS, INC.**

Photogrammetric Engineers

224 EAST ELEVENTH STREET, LOS ANGELES 15, CALIFORNIA • 275 FIFTH AVENUE, NEW YORK 16, NEW YORK

An A.A.P.G. Publication! Second Printing, 1947

TECTONIC MAP

Of The

UNITED STATES

Prepared under the Direction of the Committee on Tectonics, Division of Geology and Geography, National Research Council.

CHESTER R. LONGWELL, Chairman, PHILIP B. KING, Vice-Chairman
CHARLES H. BEHRE, WALTER H. BUCHER, EUGENE CALLAGHAN, D. F. HEWETT, G. MARSHALL KAY, ELEANORA B. KNOPF, A. I. LEVORSEN, T. S. LOVERING, GEORGE R. MANSFIELD, WATSON H. MONROE, J. T. PARDEE, RALPH D. REED, GEORGE W. STOSE, W. T. THOM, JR., A. C. WATERS, ELDRED D. WILSON, A. O. WOODFORD

A New Geologic Map of the United States and Adjacent Parts of Canada and Mexico

Geologic structure, as evidenced and interpreted by a combination of outcropping areas, bedrock, surface disturbance, and subsurface deformation, is indicated by colors, symbols, contours, and descriptive explanation. Igneous, metamorphic, and selected areas of sedimentary rock are mapped. Salt domes, crypto-volcanic disturbances, and submarine contours are shown.

The base map shows state boundaries, rivers, a pattern of cities, and 1-degree lines of latitude and longitude.

The scale is 1:2,500,000, or 1 inch = 40 miles. Printed in 7 colors, on 2 sheets, each about 40 x 50 inches. Full map size is about 80 x 50 inches.

PRICE, POSTPAID

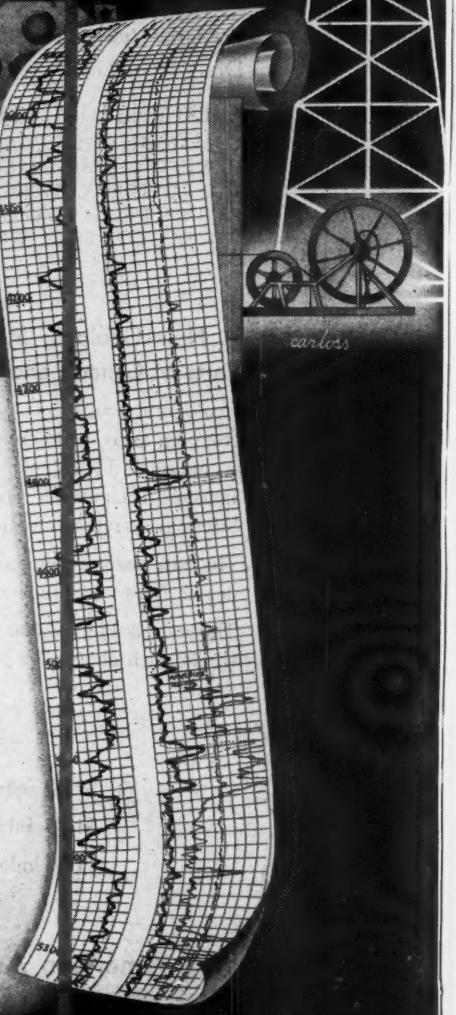
$2.00 rolled in mailing tube

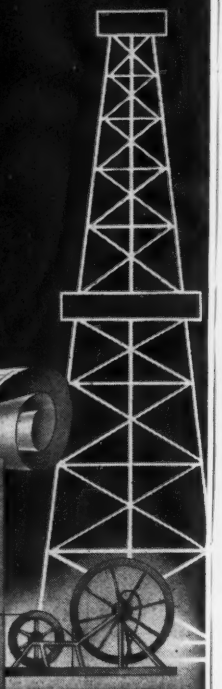
$1.75 folded in manila envelope

$1.50 in lots of 25, or more, rolled or folded

The American Association of Petroleum Geologists
Box 979, Tulsa 1, Oklahoma, U.S.A.

Accurate Information





Halliburton
ELECTRIC WELL LOGGING

A service providing . . . . . ACCURATE INFORMATION, by skilled operators using the most reliable data . . . . . SPECIAL TOOLS . . . . . companion caliper, temperature and gun perforating services.

Halliburton has dependable specialists and the highly engineered equipment to provide this service . . . . . backed by constant research to provide the best in electrical well logging technique.

HALLIBURTON OIL WELL CEMENTING CO.

DUNCAN, OKLAHOMA

Make Petroleum's New National Campaign
work for
YOU
#2 Ad
In Series
Understand Rivalry and you understand America
There's a lot more to this picture than these little boys competing for a maiden's favor. Behind it is the spirit of rivalry that moves America ahead — the competitive spirit that makes us all eager to accept a challenge to show what we can do, and be judged by how well we do it.
Rivalry is second nature to Americans. We're raised on it. It helped us win a leadership the whole world envies. Competition is in our blood. We like it. We put it to good use.
Take the Petroleum Industry, with more than 34,000 individual firms of all sizes. In every phase of this business employing 1,250,000 people, companies work to outdo rivals; compete in oil production, compete in refining, compete in research for new uses, compete in sales. That's why Americans get petroleum products at the lowest prices in the world. Tastes and prices vary of course, but gasoline in the U. S. is always the world's best bargain.
Nor does the race to make new products, better products the race to produce more and more oil to meet record-breaking demand stop with gasoline and lubricants. In a hundred differ ent fields, petroleum and its countless by-products continue the competition.
The result — better health, a chance to go more places more easily, more comfort - - more - - constantly more, for you.
THERE'S A PLUS FOR YOU IN PETROLEUM'S PROGRESS
Prepared for the oil industry by the American Petroleum Institute—Copyright, 1947

● **Send for NEW FREE Plan Book.** To help your organization tie-in and benefit from this extensive national advertising campaign locally, a detailed Plan Book has been prepared.

It offers FREE mats of seven different newspaper campaigns, display material, radio scripts, envelope stuffers — a wealth of promotional material which can be used to advantage by your firm. Send for your Free Plan Book now! Write to: Public Relations Operating Committee, Dept. 1B, American Petroleum Institute, 670 Fifth Avenue, New York 19, N. Y.

MIOCENE STRATIGRAPHY OF CALIFORNIA

By ROBERT M. KLEINPELL

This Work Establishes a Standard Chronologic-Biostratigraphic Section for the Miocene of California and Compares It with the Typical Stratigraphic Sequence of the Tertiary of Europe

450 pages; 14 line drawings, including a large correlation chart in pocket; 22 full-tone plates of Foraminifera; 18 tables (check lists, and a range chart of 15 pages). Bound in blue cloth; gold stamped; paper jacket: 6 x 9 inches.

"One must admire the painstaking determination with which so many successive associations of Foraminifera were collected, identified and tabulated. Such labour would scarcely have been thought of without the stimulus which the search for oil has given to the detailed study of Foraminifera.

"This should be standard work on the Miocene of California for years to come."
A.M.D. in "Nature," Vol. 144 (London, December 23, 1939), p. 1030.

PRICE: $5.00, POSTPAID
($4.50 TO A.A.P.G. MEMBERS AND ASSOCIATES)

The American Association of Petroleum Geologists
BOX 979, TULSA 1, OKLAHOMA, U.S.A.

JOURNAL OF PALEONTOLOGY
JOURNAL OF SEDIMENTARY PETROLOGY

	Annual S.E.P.M. Dues	Annual Non-Member Subscription
JOURNAL OF PALEONTOLOGY	$5.00	$6.00
JOURNAL OF SEDIMENTARY PETROLOGY	3.00	3.00
BOTH JOURNALS	8.00	9.00

BACK VOLUMES AT HALF PRICE
TO MEMBERS AND SUBSCRIBERS

	Per Vol.
Jour. Pal., Vol. 1 (1927) unavailable	
Vol. 2 (1928)—Vol. 8 (1934), each complete, 4 Nos.	$3.00
Vol. 9 (1935)—Vol. 11 (1937), each complete, 8 Nos.	3.00
Sed. Petr., Vol. 1 (1931), complete, 2 Nos.	1.50
Vol. 2 (1932)—Vol. 7 (1937) each complete, 3 Nos.	1.50

BACK VOLUMES AT REGULAR PRICES

Jour. Pal., Vol. 12 (1938)—Vol. 20 (1946), each complete, 6 Nos.	$6.00
Sed. Petr., Vol. 8 (1938)—Vol. 16 (1946), each complete, 3 Nos.	3.00

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
BOX 979, TULSA 1, OKLAHOMA

!!!!

COMPREHENSIVE INDEX

OF THE PUBLICATIONS OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

1917-1945

By DAISY WINIFRED HEATH

A.A.P.G. PUBLICATIONS INDEXED

1917–1945	The *Bulletin*, Vol. 1 (1917)-Vol. 29 (1945)
1926	Geology of Salt Dome Oil Fields
1928	Theory of Continental Drift
1929	Structure of Typical American Oil Fields, Vol. 1
1929	Structure of Typical American Oil Fields, Vol. 2
1931	Stratigraphy of Plains of Southern Alberta
1933	Geology of California
1934	Problems of Petroleum Geology
1935	Geology of Natural Gas
1936	Geology of the Tampico Region, Mexico
1936	Gulf Coast Oil Fields
1936	Structural Evolution of Southern California
1938	Miocene Stratigraphy of California
1939	Recent Marine Sediments
1941	Possible Future Oil Provinces of the United States and Canada
1941	Stratigraphic Type Oil Fields
1942	Permian of West Texas and Southeastern New Mexico
1942	Source Beds of Petroleum

- **603 pages, 6.75 x 9.5 inches**
- **Bound in green Buckram; stamped in art gold**

PRICE, $4.00, POSTPAID
TO MEMBERS AND ASSOCIATES, $3.00

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
BOX 979, TULSA 1, OKLAHOMA, U.S.A.

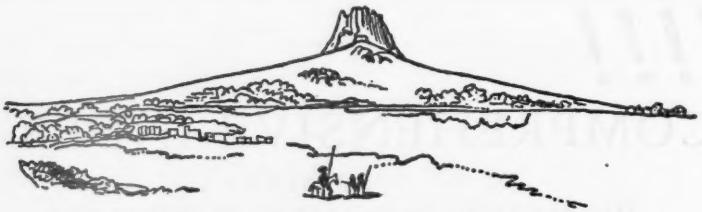


FIG. 20.—Cerro Bernal, volcanic plug. (Reproduction of sketch by Captain G. F. Lyon, 1828; redrawn by F. S. Howell.)

GEOLOGY OF THE TAMPICO REGION MEXICO

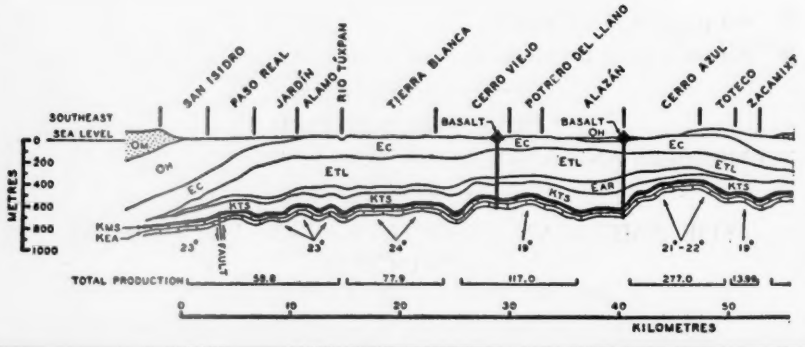
By JOHN M. MUIR
1936

"This book deals primarily with the geology of the Tampico embayment, but the author has viewed his objective with a broad perspective and presents the oil fields of that area against a background of the geologic history of Mexico. . . . (It) is an authoritative work by an expert on an area which has been one of the most important oil-producing regions of the world. The excellent areal geologic map of the Tampico embayment and the structure maps of the oil fields are significant contributions to Mexican geology. The extensive faunal lists from definite localities in each formation will be welcomed by students of earth history who seek to correlate the events in Mexico with the panorama of geologic development throughout the world."—Lewis B. Kellum, of the University of Michigan, in *Bull. Amer. Assoc. Petrol. Geol.*

280 pp., including appendix, bibliography, gazetteer, index, 15 half-tones, 41 line drawings, including 5 maps in pocket, 212 references in bibliography
Bound in blue cloth; gold stamped. 6 x 9 inches.

PRICE, $4.50, POSTPAID ($3.50 TO MEMBERS AND ASSOCIATES)

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
BOX 979, TULSA 1, OKLAHOMA, U.S.A.



In making preliminary surveys the seasoned petroleum geologist relies upon the highly sensitive American Paulin System Altimeter, whose accuracy has been proven to be better than 1 part in 1000. Easily portable and ruggedly constructed, American Paulin System Altimeters are in use by field technicians throughout the world. See your dealer . . . or write today for folder P-1.

AMERICAN PAULIN SYSTEM

Manufacturers of Precision Instruments

1847 SOUTH FLOWER STREET
LOS ANGELES 15, CALIFORNIA

Altimeters

Experience

MIDDLEWEST REGION

Over 500 Crew Months in This Area Alone!

National GEOPHYSICAL COMPANY INC.
DALLAS • TEXAS

8800 LEMMON AVE.

The shaded counties on the above map show where National crews have conducted seismic surveys in the past.

This vast amount of previous experience permits us to offer competent crews with specialized equipment and techniques for solving the wide variety of geological problems and field conditions which are encountered in this area.

This is the second of a series of experience maps which will show where National has conducted seismic surveys in various regions of the country.

AVAILABLE PUBLICATIONS OF

The American Association of Petroleum Geologists

Box 979, Tulsa 1, Oklahoma

1931 **Geologic Map of Cuba.** Compiled by J. Whitney Lewis. Folded paper sheet, 24 x 10 inches. Scale, 3/16 inch = 10 miles. Geologic column on same sheet. From Lewis' "Geology of Cuba," in June, 1932, *Bulletin* ..... $ .25

1936 **Geology of the Tampico Region, Mexico.** By John M. Muir. 280 pp., 15 half-tone plates, 41 line drawings, 9 tables. 6 x 9 inches. Cloth. **To members and associates, $3.50** 4.50

1936 **Areal and Tectonic Map of Southern California.** By R. D. Reed and J. S. Hollister. In 10 colors. From "Structural Evolution of Southern California," December, 1936, *Bulletin*. Scale, ⅛ inch = 1 mile. Map and 4 structure sections on strong ledger paper, 27 x 31 inches, rolled in tube .50

1938 **Miocene Stratigraphy of California.** By Robert M. Kleinpell. 450 pp.; 14 line drawings, including a large correlation chart; 22 full-tone plates of foraminifera; 18 tables (check lists and a range chart of 15 pages). 6 x 9 inches. Cloth. **To members and associates, $4.50** 5.00

1946 **Directory of Geological Material in North America.** By J. V. Howell and A. I. Levorsen. 112 pp. From Part II of August, 1946, *Bulletin*. 6.75 x 9.5 inches. Paper ..... .75

1947 **Possible Future Oil Provinces of the United States and Canada. Third printing.** From August, 1941, *Bulletin*. 154 pp., 83 figs. 6 x 9 inches. Paper. **To members and associates, $1.00** 1.50

1947 **Structure of Typical American Oil Fields.** Symposium on relation of oil accumulation to structure. 2d printing. Originally published, 1929. 2 Vols. 1290 pp., 425 illus. 6 x 9 inches. Cloth. Vol. 1, $3.00. Vol. 2, $4.00 ..... 7.00

1947 **Tectonic Map of the United States.** Second printing. Originally published, 1944. Prepared under the direction of the Committee on Tectonics, Division of Geology and Geography, National Research Council. Scale, 1 inch = 40 miles. Printed in 7 colors on 2 sheets, each 40 x 50 inches. Folded, $1.75. Rolled in tube 2.00

1947 **Comprehensive Index of the Publications of the A.A.P.G., 1917-1945.** Compiled by Daisy Winifred Heath. 603 pp. 6.75 x 9.50 inches. Cloth. **To members and associates,** $3.00 ..... 4.00

Bulletin of The American Association of Petroleum Geologists. Official monthly publication. Each number, approximately 150 pages of articles, maps, discussions, reviews. Annual subscription, $15.00 (outside United States, $15.40). Descriptive price list of back numbers on request.

(Prices, postpaid. Write for discount to colleges and public libraries.)

CORES...

AT ANY DEPTH OR FORMATION WITH *The* REED 'BR' *Wire Line* OR THE REED *Kor-King* CONVENTIONAL CORE DRILLS

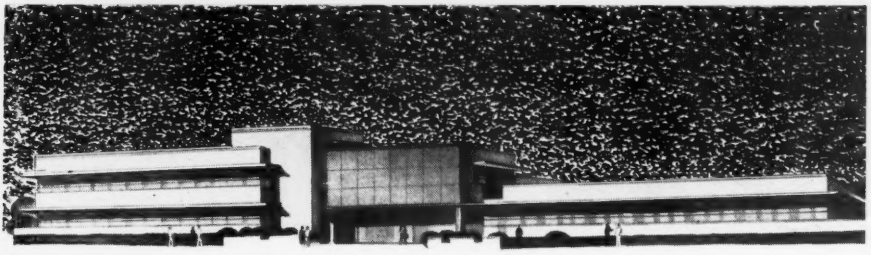
THESE CORES WERE TAKEN AT A DEPTH OF 12,856 FT. WITH THE REED "BR" *Wire Line* CORE DRILL

For conventional coring the Reed Kor-King, with its simplified construction, has advantages for uniformly good coring not to be found in any other core barrel. The Reed "BR" Wire Line drilling and coring outfit has proved itself in fields throughout the world and is especially adaptable to drilling slant holes, for those operators doing directional drilling work.

Reed

ROLLER BIT COMPANY

HOUSTON 1, TEXAS



The new G S I home at 6000 Lemmon Avenue, Dallas . . . 40,000 square feet of plant on seven acres . . . housing the most modern facilities for engineering, research and crew maintenance. We invite you to visit us.

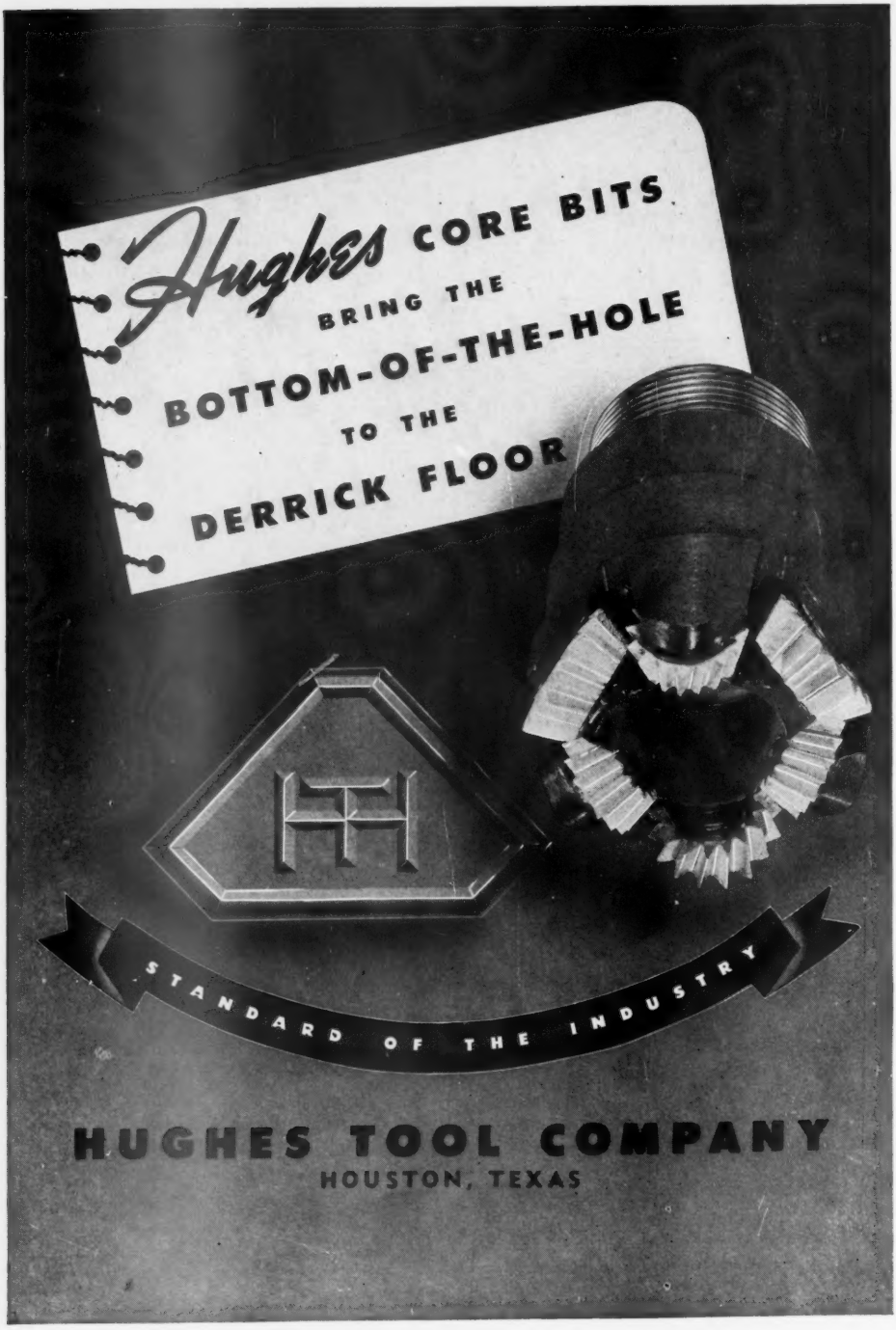
Built for Better

SERVICE

GEOPHYSICAL SERVICE INC.

SEISMIC SURVEYS

6000 LEMMON AVENUE DALLAS, TEXAS


Hughes CORE BITS
BRING THE
BOTTOM-OF-THE-HOLE
TO THE
DERRICK FLOOR
STANDARD OF THE INDUSTRY
HUGHES TOOL COMPANY
HOUSTON, TEXAS